The Utility of Unmanned Combat Air Systems Gaining Control of the Air by 2040

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ABSTRACT

The era of manned flight is not yet over, and the likelihood of its demise is not imminent. Unmanned Aircraft Systems are, however, currently assuming roles in air power that, hitherto, have been undertaken by manned aircraft. In future warfare, will it be possible for Unmanned Combat Air Systems, the next stage in Unmanned Aircraft System evolution, to undertake the tasks and accept most of the risks that until now have been the lot of military aviators? The aim of this thesis is to determine where threats to a US led alliance in 2040 are likely to come from, and whether Unmanned Combat Air Systems will be effective in undertaking all the counter-air missions that are required of a nation's armed forces. Control of the air is the foundation for all conventional military operations against an adversary with an air defence capability. If Unmanned Combat Air Systems cannot control the airspace in which they operate, and unless control can be gained by other than manned systems, then manned fighter aircraft will be required to achieve this task. This would be perverse, largely negating the purpose of utilising Unmanned Combat Air Systems. The effect that political, legal and ethical issues of using Unmanned Combat Air Systems might have upon decision makers cannot be underestimated, particularly in terms of their willingness to deploy such systems at little, if any, risk to their own military personnel. There is currently a lack of cohesion and clear thought on the future utility of Unmanned Combat Air Systems in the counter-air role, particularly within the UK, which requires cogent and informed input. This research examines these issues and will allow value to be added to the procurement decision process, and help inform future policy over the manned versus unmanned aircraft debate. Ultimately, this thesis advocates that Unmanned Combat Air Systems, capable of gaining control of the air, have the potential to offer a revolution in the way warfare will be conducted in the 21st Century.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

A2/AD	Anti-Access/Area-Denial
AAG	Air-to-Air Gun
AAM	Air-to-Air Missile
AAR	Air-to-Air Refuelling
AAS	Air-to-Air System
ABM	Anti-Ballistic Missile
ACM	Air Chief Marshal
ACMI	Air Combat Manoeuvring Instrumentation
AD	Air Defence
AESA	Active Electronically Scanned Array
AFRL	Air Force Research Laboratory
AGG	Air-to-Ground Gun
AI	Artificial Intelligence
AM	Air Marshal
AMRAAM	Advanced Medium-Range Air-to-Air Missile
ASAT	Anti-Satellite
ASBM	Anti-Ship Ballistic Missile
ASCM	Anti-Ship Cruise Missile
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASMS	Advanced Surface Missile System
ATD	Automatic Target Detection
ATI	Automatic Target Initiation
ATR	Automatic target Recognition
AVM	Air Vice-Marshal
AWACS	Airborne Warning and Control System
BLOS	Beyond Line-of-Sight
BM	Ballistic Missile
BMC2	Battle Management Command and Control
BVR	Beyond Visual Range
C2	Command and Control
C4ISTAR	Command, Control, Communications, Computers, Intelligence, Surveillance, Targeting, Acquisition and Reconnaissance
CAP	Combat Air Patrol
CAS	Chief of the Air Staff
Capt	Captain
CDE	Collateral Damage Estimation
CEP	Circular Error Probable
CFE	Conventional Forces Europe
CID	Combat Identification
CIS	Commonwealth of Independent States
CNP	Comprehensive National Power
COIN	Counter Insurgency
Col	Colonel
COMAO	Composite Air Operations
CONOPS	Concept of Operations
COP	Common Operating Picture
CSBA	Center for Strategy and Budgetary Assessment

CSCE	Conference on Security and Cooperation Europe
CSG	Carrier Strike Group
DARPA	Defense Advanced Research Projects Agency
DCA	Defensive Counter Air
DCDC	Development, Concepts and Doctrine Centre
DEW	Directed Energy Weapons
DIRCM	Directed Infrared Countermeasures
DMT	Distributed Mission Training
DoD	Department of Defense
DPOC	Deep and Persistent Offensive Capability
Dr	Doctor
DRFM	Digital Radio Frequency Memory
DSTL	Defence, Science and Technology Laboratory
EA	Electronic Attack
ECM	Electronic Countermeasures
ELINT	Electronic Intelligence
EMS	Electromagnetic Spectrum
EP	Electronic Protection
ES	Electronic Support
EW	Electronic Warfare
F2T2EA	Find, Fix, Target, Track, Engage and Assess
FJ	Fast-Jet
Fl Lt	Flight Lieutenant
FLIR	Forward Looking Infrared
FLOAAT	Function-specific Level of Autonomy and Automation Tool
G	Force of Gravity
GCS	Ground Control Station
GDP	Gross Domestic Product
Gen	General
Gp Capt	Group Captain
HALE	High-Altitude Long-Endurance
HEL	High Energy Laser
HITL	Human-in-the-Loop
HMCS	Helmet Mounted Cueing System
HOBS	High-angle Off-Boresight
HOTL	Human-on-the-Loop
HPM	High-Powered Microwave
HVAA	High Value Airborne Asset
IADS	Integrated Air Defence System
IFDL	Intra-Flight Data link
INF	Intermediate-range Nuclear Force
IR	Infrared
IRBM	Intermediate Range Ballistic Missile
IRSTS	Infrared Search and Track System
ISTAR	Intelligence, Surveillance, Targeting, Acquisition and Reconnaissance
JSF	Joint Strike Fighter
JTIDS	Joint Tactical Information Distribution System
km	Kilometre

LADAR	Laser Detection and Ranging
LFE	Large Force Employment
Lt	Lieutenant
Lt Col	Lieutenant Colonel
LO	Low Observable
LOAC	Law of Armed Conflict
LOCASS	Low Cost Autonomous attack System
LVC-IA	Live Virtual and Constructive Integrating-Architecture
MALE	Medium-Altitude Long-Endurance
Maj	Major
MAWS	Missile Approach Warning System
MEZ	Missile Engagement Zone
MOD	Ministry of Defence
MRBM	Medium-Range Ballistic Missile
MTCR	Missile Technology Control Regime
NASA	National Air and Space Administration
NATO	North Atlantic Treaty Organisation
NCADE	Network Centric Airborne Defense Element
NCW	Network Centric Warfare
NEC	Network Enabled Capability
NGLRS	Next Generation Long-Range Strike System
nm	Nautical Mile
OCA	Offensive Counter Air
OECD	Organisation for Economic Cooperation and Development
OG	Objective Gateway
OODA	Observe-Orient-Decide-Action
OTH	Over-the-Horizon
PGS	Precision Global Strike
P_k	Probability of a Kill
PLA	People’s Liberation Army
PLAAF	People’s Liberation Army Air Force
PLAN	People’s Liberation Army Navy
PRC	People’s Republic of China
QWI	Qualified Weapons Instructor
RAF	Royal Air Force
RAM	Radar Absorbent Materials
RCS	Radar Cross Section
RF	Radio Frequency
RMA	Revolution in Military Affairs
RN	Royal Navy
ROE	Rules of Engagement
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Air System
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SCO	Shanghai Cooperation Organisation
SEAD	Suppression of Enemy Air Defence
SIGINT	Signals Intelligence
SLOC	Sea Lines of Communication

Sqn Ldr	Squadron Leader
SRBM	Short-Range Ballistic Missile
TDL	Tactical Data-Links
TIBS	Tactical Information Broadcast System
TLC	Through-Life Costs
TPT	Third-Party Targeting
TST	Time-Sensitive Target
TTP	Tactics, Techniques, and Procedures
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UCAS	Unmanned Combat Air System
UCAS-D	Unmanned Combat Air System – Demonstrator
UCAV	Unmanned Combat Aerial Vehicle
UCLASS	Unmanned Carrier Launched Air Surveillance and Strike
UK	United Kingdom
US	United States
USAF	United States Air Force
USMC	United States Marine Corp
USN	United States Navy
VHF	Very High Frequency
Wg Cdr	Wing Commander
WSO	Weapon Systems Operator
WVR	Within Visual Range

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Introduction

Control of the air is the foundation for all conventional military operations against an adversary with an air defence capability. The research of this thesis into the counter-air capabilities and requirements for future Unmanned Combat Air Systems (UCAS) is unique. While there are a number of academic opinions and government 'roadmaps' on the use of UCAS gaining control of the air, these do not scrutinise in detail their full potential.[1] In his Master's thesis, Major Robert Trsek USAF, an F-15C pilot, contends that, 'In the context of future threat systems and anti-access strategies, the Air Force would be foolish not to pursue UCAV fighter technology'.[2] The United States (US) acknowledges, through its Department of Defense's (DoD) *Unmanned Aircraft Systems Roadmaps and Flight Plans,* that counter-air UCAS are intended to be in service by 2025-2030; however, these do not detail any development programmes.[3] The United Kingdom's (UK) Ministry of Defence (MOD), conversely, views that out to 2035, although UCAS, '…are likely to form part of the future control of the air force-mix…a wholly unmanned capability for the air-to-air role is unlikely to be achievable or desirable within the concept timeframe'.[4]

A number of Western countries are developing UCAS; however, these programmes do not currently include any that will enable these systems to gain control of the air, in its entirety. As at 2013, UCAS development focused on detecting and destroying Time-Sensitive-Targets (TST), utilising Intelligence, Surveillance, Targeting, Acquisition and Reconnaissance (ISTAR), and Suppression of Enemy Air Defence (SEAD) roles, the air-to-surface portion of the counter-air task.[5] The air-to-air component of counter-air warfare, a true TST issue, is as important. It is envisaged that developmental UCAS, such as the X-

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[1] While acknowledging that current US UCAS programmes do not meet requirements for an air superiority fighter, Lt Col Devin Cate, believes UCAS have potential as a future generation air superiority fighter, by 2025 – see generally, Lt Col Devin L. Cate USAF, *The Air Superiority Fighter and Defense Transformation: Why DoD Requirements Demand the F/A-22 Raptor,* Master's Degree: USAF Air University, 2003. See also, generally, Lieutenant Colonel Thomas J. Browning USAF, *Cooperative Engagement: Concept for a near Term Air-to-Air Unmanned Combat Aircraft System,* Master's Degree: USAF Air University, 2006.

[2] See Major Robert Trsek USAF, *The Last Manned Fighter: Replacing Manned Fighters with UCAVs,* Master's Degree: USAF Air University, 2007, p.30.

[3] See US Department of Defense, *Unmanned Systems Integrated Roadmap FY 2011 - 2036,* Washington, DC, 2011, p.17. Also see, Office of the US Secretary of Defense, *Unmanned Aircraft Systems Roadmap: 2005 - 2030*, http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf, (accessed 4 April 2009), Table 6.2-1, p. 74, and US Department of Defense, *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047*, http://www.govexec.com/pdfs/072309kp1.pdf, (accessed 23 January 2010), p.39.

[4] Development, Doctrine and Concept Centre, *Joint Concept Note 3/12: Future Air and Space Operating Concept*, Shrivenham, Ministry of Defence, 2012, p.4. As far as can be ascertained, this position is not based on any incisive analysis.

[5] Caitlin Harrington Lee, 'Armed and Dangerous', *Jane's Defence Weekly*, 10 August 2011, p.38. TST, ISTAR and SEAD roles are examined in Chapter's 3 and 4.

47B Unmanned Combat Air Demonstrator (UCAS-D) programme, part of the overarching US Unmanned Carrier Launched Air Surveillance and Strike (UCLASS) programme, will conduct air-to-surface and surveillance missions, but not counter-air missions.[6] The UK's *Taranis* UCAS technology demonstrator programme has similar aims.[7]

The role of UCAS should not be viewed in isolation, but rather as part of a system of systems, that aid, it can be argued, the most critical component of warfare, situational awareness. The importance that situational awareness plays in warfare, particularly in control of the air, is crucial. Network Enabled Capabilities (NEC) are required in order to establish consistent and reliable battlefield situational awareness, and will form the basis upon which UCAS are developed. The threat environment in which any weapon systems are planned to operate in will also reinforce capability requirements. Some countries adhere to different principles from those of developed democracies; it is relationships with these countries that are likely to dictate the frequency and severity of future military challenges. An understanding of where threats come from is essential. Ultimately, policy and procurement decisions are underpinned by all-source strategic and intelligence analysis. This scrutiny is fundamental, as any specious assumptions may result in erroneous conclusions, leading to the wrong strategy and procurement decisions.

Warfare in the 20th Century demonstrated the potential and performance of air power. The 21st Century promises to be a period of military revolution, sometimes referred to as a Revolution in Military Affairs (RMA), with NEC and the utilisation of UCAS coming to fruition.[8] In 1993, the director of the US Office of Net Assessment, Andrew Marshall, began to use the term RMA, in place of the then current term Military-Technical Revolution. Marshall did this to stress that, while technological advances were making a current technical revolution possible, the revolution itself would only be realised when new operational concepts had been developed, along with new military organisations.[9] Marshall argued that such a revolution was only beginning, emphasising that the humans would be

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[6] Jeremiah Gertler, *CRS Report for Congress: U.S. Unmanned Aerial Systems,* Washington, DC, Congressional Research Service, 2012, http://www.fas.org/sgp/crs/natsec/R42136.pdf, (accessed 9 October 2012), pp.47-48. A RAND report prepared for the US Navy, contends that UCAS will not be suitable in the air-to-air role, in the 2025 timeframe - see Brien Alkire and others, *Applications for Navy Unmanned Aircraft Systems*, Santa Monica, CA: RAND Corporation, 2010, p.44.

[7] QinetiQ, 'UK Taranis UAV Passes First Major Milestone', (2010), http://www.qinetiq.com/news/pressreleases/Pages/taranis-uav-passes-major-milestone.aspx, (accessed 11 May 2011).

[8] For example, for a view on the effectiveness of current NEC used by the Israeli Defence Force, see Gp Capt Alistair Byford RAF, 'Network Enabled Capability, Air Power and Irregular Warfare: The Israeli Air Force Experience in the Lebanon and Gaza, 2006-2009', *Air Power Review* 13, no. 1, 2010, pp.1-12. The importance of NEC is explored in Chapter 4.

[9] Barry D. Watts, *The Maturing Revolution in Military Affairs*, Washington, DC: Center for Strategic and Budgetary Assessments, 2011, p.3.

fundamental in its development.[10] In 1994, Andrew Krepinevich contended that an RMA is: '….what occurs when the application of new technologies…combine[d] with innovative operational concepts and organizational adaptation…[produces] a dramatic increase…in the combat potential and military effectiveness of armed forces'.[11] Marshall and Krepinevich were by no means the first to use the term RMA. An RMA was described in a Soviet military manual in 1973, '…[as] the present stage in development of Soviet military theory and practice in relationship to scientific-technical progress…'.[12] This Soviet vision of RMA was considered by some to be too narrow, concentrating on technology and weapons, rather than the importance of concepts and doctrine.[13] Although Marshall understood the Soviet's philosophy, he believed it was flawed.[14] Not all are enamoured with the concept of RMA. Professor Colin Gray, in *Another Bloody Century*, discusses the relevance of RMA, believing that too much emphasis is placed on technology, while humans will remain the critical factor.[15] The concept of an RMA is also debated fiercely in China; drawing on Russian and US writings, Chinese military authors, for example, have emphasised the requirement to exploit information, stealth (and counter-stealth) and anti-satellite (ASAT) technology.[16]

The current utilisation of Unmanned Aircraft Systems (UAS) and future potential use of UCAS could be viewed as an RMA, with the potential to bring a transformation to the way future battlespace is controlled and victory is achieved. However, there have been a number of false dawns preaching the virtues of unmanned aircraft. For example, General Hap Arnold, Chief of the US Army Air Force, predicted future possibilities, when he observed on VJ Day in 1945:

> We have just won a war with a lot of heroes flying around in planes. The next war may be fought by airplanes with no men in them at all…Take everything you've learned about aviation

[10] Colin S. Gray, *Strategy for Chaos: Revolutions in Military Affairs and the Evidence of History*, London: Frank Cass, 2002, p.viii.

[11] Andrew F. Krepinevich, 'Cavalry to Computer: The Pattern of Military Revolutions', *The National Interest*, Fall 1994, p.30.

[12] Colonel General N. A. Lomov, *Scientific-Technical Progress and the Revolution in Military Affairs*, translated, and Pubilised under the Auspices of the United States Air Force, Washington, DC: US Government Printing Office, 1973, p.v.

[13] Elliot Cohen, 'A Revolution in Warfare', *Foreign Affairs* 75, 1996, p.39.

[14] Keth Shimko, *The Iraq Wars and America's Military Revolution*, Cambridge: Cambridge University Press, 2010, p.37.

[15] See Colin S. Gray, *Another Bloody Century*, London: Weidenfeld and Nicolson, 2005, pp.105-119. Gray has been at the centre of the RMA discussion for many years; see also generally, Colin S. Gray, *SCSIOccasional Paper No 28 - the American Revolution in Military Affairs: An Interim Assessment*, Camberley: Joint Services Command and Staff College, 1997.

[16] See Michael Pillsbury, *China Debates the Future Security Environment*, Washington, DC: National Defense University Press, 2000, pp.285-291.

> in war, throw it out of the window, and let's go to work on tomorrow's aviation. It will be different from anything the world has ever seen.[17]

Although not quite prescient, Arnold's words, almost 70 years later, are gaining relevancy. Whether the ascendancy of UAS is an RMA or not, it is worth remembering that the fundamentals of war will likely remain extant. As Peter Singer states in *Wired for War: The Robotics Revolution and Conflict in the 21st Century:* '….it [war] will still involve all the unexpected confusion, mistakes, and dilemmas that go hand in hand with both technology and war. The fog of war ain't going anywhere'.[18]

It is emphasised that this thesis does not examine in detail the current or future use of UAS by either nation states, or non-state organisations. While an overview of UAS is given, the focus is on unmanned air systems that are required to operate in highly contested airspace, capable of achieving control of the air, which require major investment and infrastructure for operation; only UCAS currently fit this description. Within NATO, control of the air is classified into two subdivisions - air superiority and air supremacy. Air superiority is defined as: 'that degree of dominance in the air battle of one force over another which permits the conduct of operations by the former and its related land, sea, and air forces at a given time and place without prohibitive interference by the opposing force'.[19] Air supremacy is defined as: 'that degree of air superiority wherein the opposing air force is incapable of effective interference'.[20] Although these terms are not consistently used by commentators, they do illustrate that air power may not allow absolute dominance of the airspace all of the time. When describing control of the air, or the use of systems to obtain it, this thesis uses the terms control of the air, air supremacy, and air superiority, where each is relevant.

Standard military acronyms are used throughout this thesis, where appropriate; these are based on NATO terminology and standard convention.[21] This thesis uses the terms Unmanned Aircraft (UA), Unmanned Aerial Vehicle (UAV), UAS, Unmanned Combat Aerial Vehicle (UCAV) and UCAS. It is important to understand that UAS consist of a number of physical components and other strands: the UAV themselves, their sensors and weapons, communications links, the Ground Control Station (GCS), the personnel involved in

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[17] Jay Shafritz, *Words on War: Military Quotes from Ancient Times to the Present*, New York; Prentice Hall, 1990, p.104.

[18] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century*, New York: The Penguin Press, 2009, pp.194-195.

[19] See UK Ministry of Defence, *Joint Warfare Publication 3-63: Joint Air Defence*, 2nd Edition, Shrivenham: Joint Doctrine & Concepts Centre, 2003, p.1.6.

[20] *ibid.*

[21] All acronyms are used for both the singular and plural sense.

operating the system, and the logistics support required.[22] This may seem obvious, however, very few analysts refer to the system as a whole. A similar situation exists with UCAS terminology. At writing, there was no agreed standard definition of UCAS. The *Humanitarian Policy and Conflict Research Manual on International Law Applicable to Air and Missile Warfare*, defines a UCAV as: '…an unmanned military aircraft of any size which carries and launches a weapon, or which can use on-board technology to direct such a weapon to a target'.[23] This is a useful description for the purposes of this manual. However, the UK and US, for example, do not normally term weaponised UAS as UCAS. Until there is conformity, and for the purposes of this thesis, the author defines UCAS as weaponised UAS, utilising a level of automation/autonomy, which may also be capable of ISTAR tasks, designed to survive in highly contested airspace. This can be by utilisation of a combination of stealth features, NEC, Electronic Attack (EA), countermeasures, weapon systems capable of self-protection as a minimum, speed and manoeuvrability.

Thesis Structure

This thesis is structured to allow the reader to develop an understanding of the methodology used, and why, before giving an overview of UCAS potential. Technical capabilities and tactical doctrine are explained, in order that the reader has a basic understanding of the requirements of air power, in particular, counter-air capabilities. These are referenced appropriately to allow further examination. Ultimately, two potential future conflict points, centred on the US and its allies, and China and Iran, are examined; these allow the use of UCAS to be put into context.

Chapter 1 examines the research methodology, including analysis of a questionnaire used. This questionnaire was designed to help remove any bias the author may have had, by eliciting opinion from military aviators and engineers, UK MOD aviation analysts and engineers, and pertinent civilians. This helped establish trends on the efficacy of using UCAS, the weapon systems required, and concerns regarding recruitment, ethical, and legal issues.

Before scrutinising in detail the hypothesis of this thesis, it is important to allow the reader to develop a basic understanding of the issues involved. The purpose of Chapter 2, therefore, is to give an overview of the potential that UCAS may offer to military commanders and political leaders in the coming decades. It also gives a brief synopsis of the questions that are currently being debated regarding UAS/UCAS utility, including:

[22] Bill Yenne, *Attack of the Drones: A History of Unmanned Aerial Combat,* St Pauls, MN: Zenith Press, 2004, p.67.

[23] *Commentary on the HPCR Manual on International Law Applicable to Air and Missile Warfare*, Cambridge, MA: HPCR Harvard, 2010, p.55.

terminology; UAS/UCAS background; the future threat environment; technical issues; a short review of aerial warfare; current UAS/UCAS Roadmaps; and a discussion on the meaning of autonomy versus automation. The debate over one-seat versus two-seat fighters has been ongoing over many years; its relevance to UAS is discussed. The importance of precision navigation and weapon delivery systems, potential cost-savings, leadership challenges, and a view of UCAS operations and developments are also examined. The discussion over UCAS Concept of Operations (CONOPS) and current developments, is also covered. This chapter should give the reader an incentive to explore further. Subsequent chapters examine some of these areas in greater detail.

Chapter 3 scrutinises the evolution of UAS and the beginnings of UCAS developments. UCAS technological challenges, including the employment of UAS/UCAS within the Law of Armed Conflict (LOAC) are also examined; this is essential, as the LOAC is increasingly dominating the conduct of warfare, especially during wars of choice. The current debate over the ethical issues of using UAS is also examined, discussing its pertinence with regard to the future use of UCAS.

The aim of Chapter 4 is to develop a basic understanding of the role that air and space power play in modern warfare; this is vital in appreciating the criticality of control of the air and the counter-air campaign. Control of the air doctrine and the components required are examined, including the relevance to UCAS operations that both Boyd's Observe-Orient-Decide-Action (OODA) Loop concept and situational awareness play in warfare. The developmental path of air-to-air missiles (AAM) and other weapon systems is also scrutinised.

Chapter 5 reviews the evolution of air warfare, with the aim of establishing the importance of weapon systems, in particular, the kill probability of air-to-air systems (AAS), and tactics for future counter-air roles. Western and Chinese air-to-air doctrine is also reviewed, with a future air-to-air scenario used to illustrate the importance of weapon system kill probability. How would UCAS be utilised in 2040? Putting the future utilisation of UCAS into context is vital; the CONOPS that a military force would require, if UCAS were to be part of the force mix, is examined in more detail.

Chapter 6 examines international relations and future threats, concentrating on China and Iran, in particular their Anti-Access/Area Denial (A2/AD) doctrine. Other countries, such as Russia, Australia, North Korea, Japan and India, will play a significant part in international relations in the coming decades – many will affect the foreign policies of each other. It is not the aim of this this thesis to analyse these countries, instead, analysis is confined to China and Iran, as both these countries potentially pose the greatest risk to stability in international relations. This is considered by the author sufficient in order to illustrate potential future scenarios, while allowing the thesis to concentrate on developing an understanding of the importance of air power, in particular, the attributes required for gaining control of the air, and the potential utility of UCAS.

Finally, the conclusion consolidates and summarises the research process taken, and findings of this thesis, with the author's recommendations on the future progression of UCAS development.

Chapter 1: Research Methodology

The research methodology used in this thesis is based on conventional methods. The two main approaches to research are the scientific and ethnographic.[24] These and other methods are examined, including the utility of a questionnaire survey, before outlining the main methodologies chosen. The scientific approach is linked to a particular way of doing research in which objective measurements are taken in a controlled environment; these are repeatable, which means that alternative explanations for findings can be ruled out. The logic of this approach is that of deduction from experiments, with the aim of providing statistical results that can be considered valid and reliable. While not exclusive to the scientific approach the main type of data used is quantitative.[25] The ethnographic approach is concerned with studying culture; it is more open ended and iterative in nature than that of the scientific approach. It is concerned with meaning through investigating feelings, attitudes, values, perceptions and the interactions of people and groups. Unlike the scientific approach, the ethnographic approach can be described as more of a journey, along which learning will occur.[26] This leads to ethnographers starting their data gathering across a broad area not knowing exactly what they are going to find. This approach often means more time is spent gathering and interpreting the results than in the scientific approach, and that the data gathering is likely to start earlier. This approach has been utilised, as it has allowed the author to use appropriate colleagues and other experts as a source of material on an *ad hoc* basis.

The method for data gathering and analysis is not defined within the case study approach.[27] Critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generality of findings. However, researchers continue to use the case study research method with success in carefully planned studies of real-life situations, issues, and problems.[28] Perhaps one of the first questions to be asked when undertaking a case study is what the unit of analysis is - is it an individual, an organisation or situation? Having decided what this is, a researcher then needs to define the case study, enabling a decision on what is relevant to the research. Although the research method is not defined in the case study approach, both the scientific

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[24] H. Maylor and K. Blackmon, *Researching Business and Management*, London: Palgrave Macmillan, 2005, pp.141-149.

[25] *ibid.,* p.142.

[26] Web Center For Social Research Methods, 'Qualitative Measures', *Research Methods Knowledge Base*, http://www.socialresearchmethods.net/kb/qual.php, (accessed 4 May 2009). See also, Maylor and Blackmon, *op. cit.,* pp.144-145.

[27] *ibid.,* p.243.

[28] Sue Soy, 'The Case Study as a Research Method', *Uses and Users of Information - LIS 391D.1 - Spring 1997*, http://www.ischool.utexas.edu/~ssoy/usesusers/l391d1b.htm, (accessed 6 June 2009).

or ethnographic approaches can be used in isolation, or together. Moreover, the use of indirect data in the case study method can also be used to supplement direct data, the former including things such as reports and archival documents.

Maylor and Blackmon argue that scientific quantitative research methods, such as random sampling, which are applied to a research question with a view to providing a statistical analysis of the results, do not sit well with the single unit of analysis used in the case study approach. Instead they suggest that the qualitative method is more suited, stating: 'In a qualitative research design, you continually refine your data collection and analysis as you investigate your research problem, opening up new areas and closing off other ones'.[29] As with the ethnographic approach, the case study approach, using the qualitative method, does not seek to prove a hypothesis and normally starts from a broad research objective. Nevertheless, quantitative methods can be used in the case study approach or a combination of methods can be used, this being called multi-method research or triangulation.[30] Multi-method research has emerged because the multi-method nature of contemporary social science has convinced many researchers that solutions to their research problems require more and different kinds of information than any single method can provide.[31] Multi-method research offers the opportunity to capture information on a subject in different ways that may in turn lead to different answers. One reason for adopting a multi-method approach is to support a research project which is undertaken in stages where a variety of methods may be appropriate through the different stages of the research. For example, a questionnaire, such as the one the author has used, may be used in the first stage to try to identify key areas that are then analysed using qualitative methods. Triangulation as a research method uses several perspectives, multiple-methods, sources of data, measures and viewpoints. There are a number of advantages to adopting the triangulation method, but perhaps the most important is that it can strengthen conclusions; having used more than one source of data can remove that which is unreliable.

In order to help remove bias, and to seek peer review, the questionnaire used was originated to enable opinion from appropriate experts and knowledgeable individuals to be assessed, with the ultimate objective of facilitating analysis on whether the overarching aim of this thesis had validity. It is difficult to give a particular value to an interviewee, however, by allowing sight of their background and experience, it can be seen that there is a wide

[29] Maylor and Blackmon, *op. cit.,* p.344.

[30] *ibid.,* pp.256-261.

[31] Brewer, 'The Multimethod Approach and Its Promise', http://www.sagepub.com/upm-data/6050_Chapter_1_Brewer_I_Proof.pdf, (accessed 17 May 2009).

range, both in experience and professional roles.[32] It would have been relatively easy, and produced a far larger pool of interviewees, if this survey had been conducted by allowing the questionnaire to be answered by civilians or military aircrew selected randomly. However, the value of their opinions would be difficult to quantify. It was important that the interviewees had relevant experience of the questions being asked, whether that be military, scientific, or aspirational based. The findings have validated those areas of research that are central to this thesis, allowing these to be focused on. Valuable insight has also been gained, allowing comment and recommendations to be made on what systems UCAS will require, and also, the type of air vehicle necessary. A number of graphs are used in this thesis to show trends and any clusters. These offer a clear illustrative tendency on views gained from the questionnaire. All graphs are contained in Appendices G and H. The results from the questionnaire are examined later in this chapter, and also integrated into this thesis, where appropriate.

The literature review was wide-ranging. Strategic and military policy institutes, such as the RAND Corporation, the US Center for Strategic and Budgetary Assessment (CSBA), the Royal United Services Institute (RUSI), Chatham House, and the International Institute for Strategic Studies (IISS), provided a source of material on international relations and military capabilities and issues. A number of websites and aviation journals proved essential in tracking advances in technology. International affairs, law, and security journals, allowed for balanced opinions to be assessed for relevance. Technical and reference works have also been beneficial in allowing the fundamentals of the systems UCAS will likely use to be better understood. Relevant national newspapers also provided a rich seam of up-to-date analyses, which were be used to compare views.

In deciding the research methodology to be used for this thesis, it was an absolute requirement to be meticulous in the removal of bias from any conclusions. The author is an experienced RAF aviator and Qualified Weapons Instructor (QWI) Air Defence (AD), with some 30 years' experience, and over 6000 hours in the counter-air role. He has also been responsible for analysing potential adversary UAS/UCAS, and advising MOD projects on UAS/UCAS procurement. All of which has helped the author's research immensely. The research undertaken involves personnel and organisations with which the author has had contact during his career; hence, establishing a neutral position was paramount. In attempting to remove bias, a number of methods have been utilised. A survey of military aircrew and officers, MOD engineers and aviation specialists, and civilians, collecting views on whether UCAS can gain control of the air in future warfare in 2040, and also, ethical and motivational issues, *inter alia,* was conducted. The intention was to determine any

[32] See Appendix G.

emerging trends in thought, in particular, identifying divergence in interviewee's views, dependent on their experience and qualifications, both academic and military. Time was spent reviewing the literature surrounding the subject area in order to get an insight into the different perspectives and views held. Reviewing the available research methods led to the conclusion that the use of triangulation and the ethnographic methodology, aligned within a case study approach was the most appropriate methods for this thesis. There are a number of reasons behind this conclusion. Perhaps the most fundamental being that although this thesis investigates 'The utility of UCAS in gaining control of the air', which is on the face of it a very technical subject, scientific experimentation or measurements have not been conducted; rather analysis of opinion and technological capabilities, aligned with a review of international relations have informed the conclusions.[33] The questionnaire used enabled confirmation that the crux of the thesis warranted investigation. More importantly, the responses to questions specifically designed to elicit expert views, yielded answers that allowed robust investigation questioning the efficacy of some current fundamental maxims of counter-air warfare. The views of senior commanders were particularly revealing.

Questionnaire

Analysis of the responses to the Questionnaire have helped validate those areas of research that are central to this thesis, allowing these to be focused on, and thus helping to determine any bias towards full UCAS autonomy, semi-autonomy, or indeed, no autonomy at all. Valuable insight has also been gained allowing comment to be made on the ethical, legal and motivational issues, and what systems UCAS will require, including the type of air vehicle necessary. The following breakdown of responses allows later analysis to be put into context.

Interviewee Background and Experience

The background of interviewees has been collated, including: age groups, professions, flying experience, operational experience, academic and professional qualifications, military rank, and experience with NEC and AAM. The number of interviewees totalled seventy-five. The sample size was a trade-off between the time available to conduct and collate the interviews, and the number of interviewees it was considered necessary to allow proper analysis. For the type of research undertaken, a sample size of larger than 30 and less than 500 is considered appropriate.[34] A large proportion of the interviewees were RAF

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[33] Although trials could be conducted using appropriate simulation, at this stage it is not possible to conduct these and produce unclassified results. It is possible, however, to access a wide unclassified knowledge base, via interviews and questionnaires, which have been informed by such trials, and where appropriate, results are discussed in this thesis.

[34] Uma Sekaran, *Research Methods for Business: A Skill Building Approach*, Fourth Edition, Chichester: John Wiley and Sons, 2003, p.47.

aircrew. This was necessary because most of the questions were geared towards aircrew experience. That said, where the questions were more technical, the views of scientists and aviation specialists are just as pertinent. Finally, questions regarding the ethical and political aspects of using UCAS, and future recruitment motivations, are equally pertinent to civilians.

A total of Fifty military aviators have been interviewed; most were either current or ex-fast jet (FJ) pilots or navigators; a few have experience on other aircraft, such as the maritime Nimrod, and the Nimrod R1 Signals Intelligence (SIGINT) and Electronic Intelligence (ELINT) aircraft. The majority of the FJ crews have a background in counter-air, with some dual qualified, having flown either multi/swing-role aircraft, or are experienced in both counter-air and ground attack roles on different aircraft. The overall experience on different aircraft types is diverse, covering: Tornado F-3, F-4 Phantom, F-14 Tomcat, F-15A/C/E Eagle, F-16 Falcon, F-22 Raptor, Harrier FA-2, GR-7/9, Tornado GR1/1A/4/4A, Jaguar, Predator/Reaper UAS, Global Hawk UAS, U-2, BAE Systems HERTI UAS, MiG-17 Fresco, MiG-21 Fishbed, Nimrod R-1 and R-2, C-130 Hercules, C-17, and Puma helicopter. Nine MOD aviation analysts have been interviewed - all have a background in UAS/NEC. One ex-military interviewee is an academic instructor at the USAF Weapons School, at Nellis Air Force Base, with a background as an Aggressor pilot instructor at 'Exercise Red Flag', having flown various US and Russian fighters, including the MiG-17 and Mig-21; he also flew air-to-air combat missions in Vietnam and Laos.[35] Exercise Red Flag is a multi-faceted military training exercise, centred on flying operations. It is conducted in airspace situated in training ranges in the Nevada Desert, to the north of Las Vegas. It is considered the premier training programme for US military aviators and its allies, Integrated Air Defence System (IADS) operators, including cyber-space, covering all aspects of modern air power. Its aim is to simulate, as closely as possible, the conditions that 'warfighters' are likely to meet on operations. Red Flag was instigated as a direct result of the losses suffered by the US during the Vietnam War. The RAF has been attending Red Flag exercises since the 1970s.[36] Eleven non-aviation specialist civilians were interviewed; their views on the future ethical and motivational issues are valid. The remaining civilian interviewees are from diverse professional backgrounds, including engineering and management. A number of senior RAF and USAF commanders were interviewed, and although small in number, their views give weight to future MOD/DoD policy towards the use of UCAS. Five interviewees chose to express their views under 'The Chatham House Rule'.

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[35] This interviewee was a founder member of Exercise Red Flag, which started in 1975. Aggressor instructors use adversary tactics and doctrine, and sometimes equipment, to teach US and coalition forces how to counter these threats – see S Davies, *Red Eagles*, Oxford: Osprey Publishing, 2008, pp.34-36.

[36] *ibid.,* pp.34-37.

The youngest interviewee is 16, while the oldest is 75. The majority, 80%, are aged from 30 to 54. The majority of interviewees, 62%, are either serving or ex-serving military aircrew. The remaining interviewees are military ground personnel, MOD/aviation analysts and civilians. When considering whom to interview, it was decided that the majority should be FJ aircrew, experienced in the air defence role. This is important, as their views on the technical and tactical aspects of conducting counter-air missions are crucial, particularly concerning the type of air vehicle UCAS requires, and, also which systems/weapons would be effective.

The majority of military personnel interviewed were squadron leaders and below. This was to be expected, as these officers form the majority of serving FJ aircrew. The survey is not intended to be senior officer centric. It did, however, seek, the views of the current RAF Chief of the Air Staff (CAS), a former RAF CAS, the Chief of Defence Intelligence (2012), a former Air Member for Personnel and recently the Commander-in-Chief Air Command (2012), the Deputy Chief of Defence Staff, DCDC (2011), and the Chief Executive of the Services Pensions and Veterans' Agency. The current commander of the USAF 9th Air Force, Air Combat Command, responsible for 480 aircraft, including the F-22, also completed the questionnaire. A former air marshal responsible for Information Superiority within the UK MOD, and four other US military personnel were also interviewed.

Although the interviewees have a diverse number of academic and professional qualifications, all military aircrew are qualified air pilots, air navigators, or Weapon Systems Operators (WSO), in addition to any other qualifications they possess. A qualification of a QWI (AD) indicates these aircrew are trained to teach air defence tactics, including air combat manoeuvring, and weaponry to an advanced level. This qualification is considered to be the pinnacle of a fighter pilot or navigator's professional achievement, and is internationally recognised as being achieved only by those fighter aircrew who have reached the highest standards. It is usually these QWI who inform the procurement and evaluation process for future combat air platforms.[37] Eighteen of the aircrew are AD QWI.[38]

Fifty-five percent of aircrew interviewed have between 2000-4000 hours FJ experience, either on air-to-air fighters, air-to-ground bombers, or swing-role fighter/bombers. Two of the FJ aircrew interviewed both have less than 1000 hours FJ experience. At the other end

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[37] See Wg Cdr Justin Reuter RAF, 'Qualiied Weapons Instructors Course', in *25 Years of Air Defence: Tornado F3,* Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.112-115.

[38] See Appendix G for details of military interviewee rank, and all interviewee professional and academic qualifications.

of the spectrum, a number of FJ aircrew have over 5000 hours FJ experience. All aircrew interviewed have had some operational experience. Most have flown on operations over Iraq, in either the 1991 or 2003 Gulf War. Those who have not experienced operations in Iraq, Afghanistan, Bosnia, Kosovo, or Libya, have operated in the Falkland Islands, and carried out Quick Reaction Alert (QRA) duties in the UK and Europe, during and post the Cold War. Non-aircrew military personnel have all seen operational duty on various operations, including in Combined Air Operation Centres. There have been no air-to-air engagements involving British forces on operations since the 1982 Falkland's War. However, having had experience of operating in large Composite Air Operation (COMAO) exercises, conducting counter-air missions, the majority of those interviewed have experience of the importance of NEC and Command and Control (C2). Seventy-seven percent of military interviewees have experience with airborne Tactical Data Links (TDL). One-hundred percent of aircrew interviewed have some TDL experience. Thirteen percent of military/MOD interviewees have experience with simulation/ground-based data-link. This is important, as experience with TDL/data-links gives insight into the value NEC can bring to the conduct of warfare. Overall, 90% of relevant interviewees have some form of experience with the concept of NEC.[39]

Sixty-seven percent of FJ aircrew interviewed have experience with the Radio Frequency (RF) AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) and the Infrared (IR) Advanced Short Range Air-to-Air Missile (ASRAAM). Twenty-one percent have experience with RF Skyflash/AIM-7 and early Sidewinder IR class AAM only.[40] These types of AAM are significantly less effective than AMRAAM and ASRAAM, tending to lead to a requirement for visual combat with an adversary.[41] A number of aircrew have experience with the AIM-54 Phoenix AAM, which was carried on the F-14 Tomcat, and the Meteor AAM, currently in development for the UK and four other European nations.[42] It is those aircrew experienced with Meteor, AMRAAM and ASRAAM type AAM who are able to give the most pertinent comments on the employment of AAM in future air warfare.

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[39] See Appendix G for details of aircrew flying hours, operation and TDL/NEC experience.

[40] Skyflash and AIM-7 class AAM are semi-active RF missiles, which require guidance from a fighter's own radar – see Robert Hewson (ed), *Jane's Air-Launched Weapons*, Coulsdon: IHS Jane's, 2011, pp.96-100. This severely limits engagement opportunities, and also, results in a within-visual-range situation developing. AMRAAM are able to guide using their own radar seekers, in certain situations – see *ibid.,* pp.102-108.

[41] For a description of the advantages of AMRAAM, see Sqn Ldr Steve Kilvington RAF, 'Fox 3: AMRAAM', in *25 Years of Air Defence: Tornado F3*, Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.25-29. For a comparison of ASRAAM and Sidewinder AAM, see Wg Cdr John Shields RAF, 'Unprecedented Lethality: ASRAAM', in *ibid.*, pp.22-24.

[42] The Meteor AAM will be a huge leap in capability, giving a far greater stand-off capability than any other Western AAM currently in development - see Hewson, *op.cit*., pp.65-72.

Questionnaire Analysis

Questions asked of interviewees were designed to elicit opinion on a number of issues concerning the utility of UCAS. Some questions concentrated on the aerodynamic and stealth capabilities of the UCAV itself. Others sought to establish any trend in views regarding the perceived capability of UCAS being able to effectively undertake counter-air missions, either semi-autonomously, or fully autonomously. Three questions, in particular, sought to establish whether a future UCAV would require the capability to conduct highly agile air combat manoeuvring, in order to either achieve a kill, or defend itself against a highly agile adversary. In attempting to define the weapon systems which a future UCAS will require, it is necessary to decide whether the UCAV will need the same attributes of current counter-air fighters, in airframe performance, sensors and weapons. In order to achieve this, it is essential to establish which attributes are important, desirable or unnecessary. For example, is the ability to conduct highly agile air combat essential, and is it still vital for a fighter to have a gun. This may well be true currently, but will it remain so by 2040?[43] Also, the question needs to be asked: how much emphasis should be placed on stealth, NEC, EA, aerodynamics, endurance, and payload?

Third-Party Targeting (TPT) capabilities will be central to the effectiveness of UCAS.[44] NEC will play a pivotal role in achieving this. Opinion was sought as to viability of TPT in all three phases of an air-to-air engagement: Beyond Visual Range (BVR), Within Visual Range (WVR), and close combat. The purpose of this question is to seek judgment on when these methods will become possible. An important consideration is whether there are any legal or political concerns which need to be considered when pursuing the procurement of autonomous systems. Also, will future recruitment to the RAF and other air arms be affected by the predominance of air combat systems being unmanned and autonomous? Three questions have been designed to elicit approximate statistics regarding the frequency aircrew have been required during training sorties to: (1) - enter the visual merge, in order to kill an adversary; (2) - been required to conduct air combat manoeuvring to either achieve a kill, or defend against being killed, and (3) - been required to use the gun to achieve a kill.**[45]** The purpose of these questions is to establish what

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[43] For a background on the utility of the gun in air combat, see generally, Anthony Williams and Emmanuel Gustin, *Flying Guns of the Modern Era: Development of Aircraft Guns, Ammunition and Installations since 1945*, Marlborough: Crowood Press, 2004.

[44] TPT is the ability of a system/platform to effectively use information from another system/platform, in order to conduct its mission – ultimately, instigating delivery of weapons from the system's own vehicle, or from another system, and in certain scenarios, guidance of weapons. For an example of TPT, see Byford, *op. cit.,* p.5.

[45] These sorties are Large Formation Employments exercises, such as, Red Flag, Tactical Leadership Programme and other COMAO exercises - see Wg Cdr Justin Reuter RAF, 'Red Flag', in *25 Years of Air Defence: Tornado F3,* Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.30-34.

emphasis is likely to be needed in these three phases of an engagement, when considering any preference towards weapon systems development. Where percentages are given as responses to questions, they are not intended to be totally accurate. Many aircrew have flown in a large number of these types of training exercises, some covering decades of flying. No aircrew keeps an exact tally of their kills achieved, or by what method. Their answers, therefore, are a best estimate of what they consider to be kills achieved from relevant sorties. The answers do, however, indicate a trend. This trend has helped examine the types of weapons future UCAS will require. The results of the interviews are largely qualitative, rather than statistical. They have, however, allowed with a high level of confidence, further research and analysis to be conducted, in the knowledge that the process has been peer reviewed, and found to be fundamentally sound. Where interviewees are quoted, their details are footnoted once; any further quotes from the same interviewees in this chapter were taken from the same questionnaire. The following are the results of the questionnaire.[46]

NEC and Requirement to Enter the Close-Combat Fight

Ninety-five percent of interviewees believe NEC is vital in effecting control of the air in 2040, while 5% believe it is highly desirable. Essentially, all believe NEC will provide a very important function in future warfare. These figures added integrity to the author's hypothesis that NEC is crucial to situational awareness and success in future warfare.

There have been a limited number of air-to-air engagements in the modern era, which, for the purpose of this study, is defined as post 1990. Pre-1990, BVR air-to-air engagements were conducted using semi-active RF and IR AAM, whereas post-1990 saw the 1991 Gulf War, which, while still a semi-active AAM air-to-air war, can be used as a benchmark for future BVR air-to-air engagements. The 1999 air campaign in Kosovo saw AMRAAM used for the first time against an adversary. The Vietnam War and the Israel/Arab conflicts of the 1960/70s were the last known occasions when the gun was used in air-to-air engagements, to any great extent.[47] Three questions were asked in order to elicit opinion on the number of times aircrew have been required, during large training sorties, to enter the visual merge, in order to kill an adversary; been required to conduct air combat manoeuvring to either achieve a kill, or defend against being killed, and been required to use the gun to achieve a kill. These were asked to determine what emphasis is likely to be needed on these three phases of an engagement. Appendix H details the responses to the requirement to enter

[46] Details of all interviewees are in the bibliography.

[47] Two AAG kills were achieved by Sea Harriers during the 1982 Falklands War - see Jeffrey Ethell and Alfred Price, *Air War South Atlantic*, London: Sidgwick & Jackson, 1984, pp.233-245. Analysis of air-to-air engagements from the Vietnam War to the present is included in Chapter 5 of this thesis.

the visual merge, to conduct air combat manoeuvring, and the use of the air-to-air gun (AAG). Defined as a percentage, the majority, 78%**,** of FJ air defence aircrew have been required to enter the visual merge, in order to kill an adversary, on less than 10% of COMAO sorties. Thirteen percent have been required to do so between 10 – 15% of occasions, with 9% between 16 – 20% of sorties. Thirty percent of aircrew have conducted visual air combat manoeuvring, post-merge, in order to achieve a kill, on less than 3% of their COMAO sorties, with 39% less than 5%. Seventeen percent have been required to do so on less than 10% of missions, with 14% on greater than 10%. Nineteen percent of aircrew have never used the AAG in a COMAO training sortie, while 28% have used the gun on less than 1% of sorties. Twenty percent have used the gun less than 2%, with 31% less than 5%. Two percent have used the AAG on 5% or greater. The majority of those aircrew that have never used the AAG, have 2000 - 3000 hours front-line flying experience.

All those who stated that they were required to enter the visual merge between 16 – 20% of occasions, have had no experience of AMRAAM or ASRAAM, or their equivalents, or have stated that Rules of Engagement (ROE) constraints have caused this to occur.[48] Although those experienced with the most modern AAM were required to enter the visual merge less often, the analysis indicates that BVR AAM and tactics do not always allow fighters to remain outside of the visual combat environment. Significantly, AAM probability of a kill (P_k) was not considered with this question. The BVR and WVR analysis leads to the conclusion that it is likely there will be a need for a UCAV to enter the classic visual merge on occasion, in order to achieve a kill – if weapon systems, combined with NEC, do not obviate this requirement by 2040. The usefulness of an air-to-air gun is more debatable, in particular, when employed in high-intensity air warfare. The question is - does a gun need to be procured, and if so, at what cost? Also, even if a gun should be included as part of a UCAV's weaponry, could a UCAV use it successfully? However, while difficult to quantify, the gun does not play a significant factor in air-to-air engagements, during training sorties. Further analysis of actual air-to-air engagements seeks to establish the usefulness of including a gun into a UCAV.[49]

Third Party-Targeting

Having the capability to conduct TPT when utilising UCAS will be fundamental to the system's effectiveness. It will also dictate the type of air vehicle and range of weapon systems UCAS will require in order to optimise such effectiveness. Three phases of an

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[48] For the principles of ROE, see RAF Air Warfare Centre, *AP 3002 - Air Warfare*, 1st Edition, High Wycombe: Media Services HQSTC, 2009, Chap 1, pp.10-11.

[49] See Chapter 5.

engagement were considered – BVR, WVR, and close-visual combat.[50] For each phase it was asked whether TPT was possible now; if not, when it might be, or if it would never be thought possible. Military personnel and MOD/aviation analysts answered these questions. Eighty-two percent of interviewees believed BVR TPT is possible now, with 15% believing it will be by 2020. Three percent believed it will be possible by 2040. One-hundred percent of those interviewed believed it is either possible now, or by 2040. Sixty-one percent believed WVR TPT is viable now, with 21% by 2020. A further 11% believe it will be possible by 2040. Four percent stated it may be possible, but do not know when, with 3% stating they don't know. Overall, 97% believe WVR TPT is possible now, or within the next 30 years. Unsurprisingly, only 5% thought close-combat TPT is viable now. More surprisingly, 54% believe it will be viable by 2040. Eighteen percent thought it will be possible, but cannot say when, with 12% stating they do not know. Eleven percent believed it will never be possible. The majority of MOD/aviation analysts believed it will be possible.

Open sources confirm that BVR TPT is currently conducted.[51] WVR TPT is more difficult to quantify however; if an adversary is manoeuvring aggressively, it is likely to become more difficult to achieve success the closer to an adversary the fighter or the weapon gets. Although TPT is currently used on some systems, its classification makes it somewhat difficult to quantify. That said, as a basic principle of operation, its viability is unclassified. Current TPT is achieved via TDL, such as those used in Airborne Warning and Control System (AWACS) E-3, F-3, F-15, F-16, F-18, and ground- and sea-based units. This capability has been available for over ten years, and its utility is continually being expanded. It is not known if close-combat TPT is currently achievable; however, it is the most dynamic of any air-to-air engagement, requiring a high level of skill by aircrew to manoeuvre their aircraft, and coordinate weapon systems, and other aircraft. Close-combat TPT will be the most difficult technological hurdle. It may be possible in the future, but to what degree is difficult to predict. All of these processes will be underpinned by NEC.

[50] For the purposes of this thesis, BVR is defined as being greater than 10 nm from an adversary. WVR is defined as being between 10 and 2 nm of an adversary. Close-visual combat is defined as being within 2 nm of an adversary - see S. Schallhorn and others, *Visual Search in Air Combat,* Pensacola, FL: Naval Aerospace Research Laboratory, 1991, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA241347,, (accessed 12 August 2009), p.8.

[51] For example, see a brief from Brent Nave and Robert McWhorter, 'Third Party Targeting of SLAM-ER Weapon in Flight via Link-16 Surveillance Messages', (2011), http://www.idlsoc.com/Documents/Symposiums/IDLS2005/IDLS2005_Thurs_1115_Main_Stream_Brent_Nave.pdf, (accessed 10 October 2011), slides.7-10.

Questions remain, however. Will TPT continue to develop to the extent that it allows UCAS, and other systems, to conduct all phases of the counter-air mission? If only certain phases of this mission are possible, what constraints does that put on UCAS? Ultimately, if reach-back to C2 is lost, will NEC allow the 'system' to operate autonomously? If TPT is effective for all phases of an air-to-air engagement, the requirement for highly agile dynamic manoeuvring will be negated, for what is currently termed 'the visual fight', at least. This axiom could be said for all future air combat systems, manned or unmanned. Issues such as ROE will continue to form part of the decision matrix when conducting counter-air operations. Situational awareness, allowing discrimination and the mitigation of fratricide, will also form an essential part.

UCAS Airframe Characteristics and Manoeuvrability Requirements

Will it be necessary to conduct highly agile manoeuvring, either for general survival, or for manoeuvre in the 'visual' phase of a combat engagement? What aerodynamic capabilities would counter-air UCAS require? Will stealth be of crucial importance? The capability of current modern air-to-air fighters is based on a number of fundamental principles, excluding fifth-generation stealth technology: the ability to fly at high altitude – 50, 000 feet+, to fly at high speed – Mach 1.5+, and to be highly manoeuvrable.[52] The attributes of height and speed allow for an increase in the ability to launch an AAM at further range from an adversary, than that of a slower and lower fighter. The ability for a fighter aircraft to fly high and fast gives an AAM, once launched, increased energy above its own launch speed. This extra energy can achieve a greater advantage by increasing the $R_{Maximum}$ and $R_{no\text{-}escape}$ of an AAM.[53] In addition to the $R_{maximum}$ and $R_{no\text{-}escape}$ of an AAM, the distance between opposing fighters at AAM impact, referred to as F-pole, is of great significance; this distance can mean the difference between winning and losing an engagement where both fighters are exchanging AAM. F-pole can be greatly increased by the higher and faster an aircraft can fly.[54]

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[52] For an excellent overview of the capability requirements for modern air superiority fighters, see Anthony Thornborough, *Modern Fighter Aircraft: Technology and Tactics,* Sparkford: Patrick Stephens Ltd, 1995, pp.53-100.

[53] $R_{Maximum}$ is the maximum range an AAM will travel, once launched from an aircraft, before intercepting a target - see Brian T. Schreiber, William A. Stock, and Jr. Winston Bennett, *Distributed Mission Operations within-Simulator Training Effectiveness Baseline Study,* Mesa, AZ: Lumir Research Institute: Air Force Research Laboratory, 2006, Appendix G, pp.27-32. $R_{no\text{-}escape}$ is the no-escape range of an AAM, which is the range, inside which an adversary cannot escape a threat's AAM, by manoeuvring, normally at 9 G (force of gravity), sustaining the same speed, although this can vary - see *ibid*.

[54] For, arguably, the definitive discourse on the importance of AAM dynamics, including the significance of F-pole, see Robert L. Shaw, *Fighter Combat: Tactics and Maneuvring*, Annapolis: Naval Institute Press, 1985, pp.51-52.

How much emphasis needs to be placed on agility in the design of either manned or unmanned systems? Manoeuvrability may allow for survivability, when conducting close visual combat, or a last-ditch missile defence manoeuvre against an adversary's AAM or SAM. However, in the coming epochs, will it be the agility of the airborne vehicle, or the agility of its weapon systems, that are the mitigating factor in this phase of an engagement? If agility is vital, then a UCAV has the potential to fulfil this requirement to a very high degree, whereas a manned fighter is constrained by human physiology. A human can sustain a maximum of approximately 9 G, and then only with the aid of anti-g systems, such as anti-g suits, and even then only for limited periods.[55] UCAV airframe strength would still need to be considered. It may be possible that the weapon systems are robust enough to conduct all the manoeuvring necessary in the close-in visual arena. Helmet-Mounted-Cueing-Systems (HMCS), aligned with High-Angle Off-Boresight (HOBS) AAM, such as ASRAAM and AIM-9X, which are currently in use, could militate against the need for this type of combat.[56]

Fifty percent of interviewees believe a UCAV will not need to be highly agile in 2040, with 25% stating that it would, with no caveats. Fifteen percent believe it will be desirable, with 20% for survivability reasons, with the ability to conduct defensive manoeuvres against SAM or AAM systems. Thirty percent believe a manned fighter would not need to be highly agile in 2040, with 24% stating it would be, with no caveats. Thirty-two percent believe it will be desirable, with 14% for survivability reasons, with the ability to conduct defensive manoeuvres against situational SAM or AAM. Forty-seven percent of interviewees believe it would not be necessary for a UCAV to be able to conduct highly agile close combat in 2040, with 27% stating it would, with no caveats. Twenty-four percent believe it will be desirable, with 2% for survivability reasons, with the ability to conduct defensive manoeuvres against SAM or AAM.[57]

Twenty-five percent believed that both a manned fighter and a UCAV would need to be highly agile. While this view is consistent, the differential for not requiring being highly agile, 50% and 31% respectively, is interesting. The difference being that most interviewees believe that weapon systems should be able to prevent the UCAV from needing to engage in this type of fight. The views on the requirement for a UCAV not to be highly agile are more consistent, although only one interviewee believes it is important for

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[55] See Dr Kent Gillingham and John Fosdick, *High-G Training for Fighter Aircrew*, Brooks Air Force Base Medicine: USAF School of Aerospace, 1988, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA196171, (accessed 9 May 2011), pp.12, 16-18.

[56] For description of HMCS and HOBS AAM, such as the ASRAAM and AIM-9X, see Hewson, *op. cit.*, pp.38-41, and 44-50.

[57] See Appendix H for breakdown of views and experience of interviewees.

self-defence. The overall result is that approximately 70% believed a manned fighter will need to be highly agile, while only 50% believed a UCAV would need to be. This begs the question: why is this not the case for a manned fighter? Would the same weapon systems not be available?

The overarching attributes that the interviewees believe a UACV would require vary. The most prominent of these is reach/endurance/persistence, followed by speed, the ability to use the full height envelope, stealth and agility. Endurance and reach will be fundamental strengths of UCAS; the ability to fly at high altitude and speed is also an important consideration. Although stealth was not at the top of requirements, it is interesting to note that, in the responses to a different question, 63% of interviewees view stealth in 2040 as crucial, 30% as desirable, with 7% stating that it would not be crucial. Most believe that stealth will play an important part, but it will need to be in all domains, not just the RF, but also in the IR and visual spectrums. In an interview in 2010 with the RAF's CAS, ACM Sir Stephen Dalton, stated that he believed that stealth will continue to be crucial.[58] His predecessor, ACM Sir Glen Torpy, is of the same opinion, although he caveats that stealth needs to be balanced against the requirements for agility and speed.[59] Air Marshal (AM) Christopher Nickols, the 2011 Chief of Defence Intelligence, and a former Commandant of the RAF's Air Warfare Centre, views future stealth as important, but not in its present form.[60] A former RAF Commander-in-Chief Air Command, ACM Sir Simon Bryant, believes stealth, persistence, height and weapon systems to be the critical capabilities for future UCAS.[61]

A common belief is that an adversary's situational awareness will need to be destroyed, by whatever means necessary, whether by stealth, cyber, EA, or a combination. Overall, 63% of interviewees believe it would be a crucial requirement for a UCAV to have stealth attributes, with 30% viewing it as highly desirable. Seven percent believe that it will not be crucial. The F-22 has been designed with stealth in mind.[62] The forthcoming F-35 Joint Strike Fighter (JSF) also has stealth as a significant part of its design. However, is stealth the panacea? Will future adversaries develop counter-stealth technology that render the present advantage void? Is there a cost benefit trade-off with other systems or airframe

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[58] ACM Sir Stephen Dalton RAF - Chief of the Air Staff - 2010, (Interviewed 12 January 2010).

[59] ACM Sir Glen Torpy RAF - former Chief of the Air Staff, (Interviewed 11 October 2011).

[60] AM Christopher Nickols RAF - Chief of Defence Intelligence - 2011, (Interviewed 12 September 2011).

[61] ACM Sir Simon Bryant RAF - Commander-in-Chief RAF Air Command - 2010, (Interviewed 30 March 2010).

[62] For F-22 development background and capabilities, see Paul Jackson (ed), *Jane's All the World's Aircraft 2011-2012*, Coulsdon: IHS Jane's, 2011, pp.788-792.

characteristics? Fundamentally, it appears that some interviewees may be viewing stealth as the solution to all the problems with which an advanced IADS can confront combat aircraft. Stealth technology will remain important, but how much is debateable.[63]

Ethical and Political Implications

Issues concerning the ethics of using autonomous systems to enforce government policy, including interstate warfare, and the political implications surrounding any decisions to do so, will need to be addressed, particularly before any decisions on procurement are made. These issues are currently causing debate within academia and governments worldwide. It is worth remembering, however, that these types of systems have been used for centuries. Bombs, artillery, cruise missiles, ballistic missiles, AAM, are all unmanned, of course, but should these be regarded as being in the same family of systems as UAS/UCAS?[64] Nonetheless, there is certainly some deliberation whether it is ethical to use UAS/UCAS in warfare. It gives an unfair advantage, is one common view. Another is that it shows that a country is not prepared to risk its own people in warfare, therefore, taking the moral 'low-ground'. These are questions worth debating. A just and moral cause has been part of societies' principles for many hundreds of years; but would any nation consider not using technology because of moral concerns, if an adversary did not have these concerns, thereby offering them an operational and strategic advantage – particularly if national survival was at stake?

It is emphasised that this thesis is, in the main, researching the role of UCAS gaining control of the air in its purist sense - specifically, in air-to-air engagements. The counter-air roles of SEAD and strike will, by their nature, incur more debate concerning collateral damage and civilian casualties. If the perceived thinking is that there is a huge ethical ambiguity in using these systems, will this skew development and procurement of UCAS? In the first instance, it needs to be established whether there are really any major issues, or if this is just a perception of a few. The views of senior RAF and USAF commanders are particularly pertinent. ACM Dalton stated he '…has no moral concerns, however, society has a way to go before accepting an autonomous war-fighting/killing system'. AM Nickols is neutral, opining that, '[we] are already using UAS and [are] tackling moral and political issues'. ACM Torpy believes that it is, 'a moral component that hasn't been fully investigated, and needs to be thought through by policy makers…[it] depends on willingness to accept political risks'. ACM Bryant believes, 'Checks on C2 will need to be rigid. [It will be] driven by levels of confidence in the system. [I am] concerned if it doesn't work, [which] would inhibit utility. If all of this is satisfied, then it is morally OK…if politicians

[63] This is discussed further in Chapter 4.

[64] Whether the LOAC allows the use of UAS/UCAS is examined in Chapter 3.

can be satisfied, then it is OK'. At the other end of the spectrum, perhaps, are the views of younger officers and aircrew. Flight Lieutenant Jonathan Skinner, a 26 year old RAF pilot, with approximately 350 hours on the Tornado F-3 and 200 hours on the Typhoon, believes that, 'It [UCAS] would just need extensive testing…A decision matrix can be inputted into UCAS as easily as trained into a pilot. The necessary human input is just at the programming stage'.[65] Colonel Gaillard Peck USAF (Retd), a vastly experienced US fighter pilot, having flown in the Vietnam War, and is one of the founding members of Exercise Red Flag, simply states, 'Go for it! There is no substitute for victory'.[66] Major General Lawrence Wells, Commander 9th Air Force, has '…no issues, as long as the ROE considers collateral damage'.[67]

The emphatic response to this question is that there seems to be little concern on ethical or political issues, overall, in the future utility of UCAS. Eighty-six percent of interviewees have no issues, with 14% having some reservations. It could be argued that those interviewees that have no issues have not thought though the implications of this technology. However, most have direct experience with combat operations, with some having been Air Component Commanders during conflicts, responsible for the conduct of all air operations; others have operated UAS in Iraq and Afghanistan, while most aircrew are immersed with the doctrinal and collateral damage issues of large wartime missions. That is to say, their views, including those of senior officers, need to be considered. Most civilian interviewees have no concerns, with 17% having some issues – broadly in line with military interviewees. A British Army lawyer familiar with the LOAC, stated the ethical and legal implications for the use of UCAS are no different from those applicable to any weapon system. The LOAC will still need to be applied, and it is there to protect the person authorising the mission, as well as the civilian population and infrastructure.[68]

From a political viewpoint, obtaining the views of someone with a direct link to current political thought was important. An interview with the then UK Secretary of State for Defence's (Liam Fox) Special Adviser, Oliver Waghorn, was conducted in June 2011. Waghorn's response to the moral and political question offers an interesting perspective on the debate. Summarising his response:

> [it] could weigh heavily on a politician's mind. [There is a] need to understand all the risks. [There] may be concerns whether an autonomous system can make the right decisions

[65] Flight Lieutenant Jonathan Skinner RAF, (Postal Questionnaire, dated 24 March 2010).

[66] Colonel Gaillard Peck USAF (Retd), (Questionnarie completed electronically and sent by email, 3 August 2010).

[67] Major General Lawrence Wells USAF, (Postal Questionnaire, dated 11 January 2013).

[68] The author interviewed this army lawyer under the Chatham House Rule, on 17 November 2011.

> without a human in the loop. The safety of aircrew may be an incentive, however, it depends on the scenario – what is the Grand Strategic context? [Politicians] would probably be loath to allow it, unless it was proven to be one-hundred per cent effective. The unknown context of UCAS would make it very difficult for politicians to sign up to the idea. [Would be] more content in an air-to-air scenario, due to collateral issues. [Ultimately] success may invite a reassessment. [The] default would be risk adverse.[69]

Waghorn's views are fairly comprehensive, which he emphasised are likely to be consistent with many politicians. It was made quite clear to the author that Waghorn was speaking on behalf of his boss, the Secretary of State. It may be coincidental, but subsequent to the Waghorn interview, on a visit to the RAF detachment at the Italian Air Force base at Gioia del Colle in Italy, Liam Fox spoke to a group of Typhoon pilots, who were conducting missions in Libya, as part of Operation Ellamy. Fox asked them how many thought they would be flying a fast-jet after the Typhoon had finished service in the RAF. He stated that the Typhoon would likely be the RAF's last manned fighter.[70] Whether he was bantering or not, it illustrates that politicians are at least contemplating the idea of unmanned aircraft fulfilling the counter-air role. It may be that politicians will be risk adverse to the use of UCAS. It remains to be seen, however, if the momentum of development, and the likelihood that technology makes these systems viable, whether any residual ethical or political concerns are dealt with. It is apparent that military aviators and RAF commanders have a practical view of the future utility of UCAS. If operated within the LOAC, then the overwhelming majority do not have concerns.

Waghorn's comments are perceptive; it is the political will to use UCAS that will probably incur barriers. The author believes that if managed correctly, the general public would be mostly accepting of these systems, and it seems that the majority of military personnel would have few concerns. While not wanting to prevent reasonable discussion *vis-à-vis* the ethical and political issues, it is the author's opinion that debate should not hinder UCAS development unduly, if in fact, there are no real barriers to overcome. Politicians will generally be adverse to new technologies, until their effectiveness is proven. However, it should not prevent UCAS development and future use – the effectiveness of the system, within the LOAC, should be the overarching concern.

Motivation for Personnel Joining an Air Force

Will a UAS/UCAS centric air force engender the same motivations for joining as currently? What motivates someone to want to join an air force to fly? Is it the act of being able to fly a complex, fast and very potent aircraft? Is it the prospect of flying helicopters in extremely

[69] Oliver Waghorn, 'Special Adviser to the UK Secretary of State for Defence,' (Interviewed 24 June 2011).
[70] Interview with an RAF Typhoon pilot, under the Chatham House Rule - 24 August 2012.

challenging scenarios? Alternatively, is it merely the act of flying, in fact, flying anything? Is this an important issue at all? Some do not actually join to fly; a significant number of personnel know that they can never fly, but decide do join because they wish to be involved in aviation *per se*. Historically, the desire to join one's own air force has been predicated on events that have brought flying to the attention of the general public. The Battle of Britain has been used as an exemplar of the spirit of the British people during a time of extreme adversity. RAF fighter pilots, in particular, were, and still are, heralded as the true heroes of the Battle. While there is no doubt that these pilots were vital in gaining control of the air over the UK and the English Channel, they were but one small part of a very large team.[71]

The motivation to join the RAF may well initially have been the desire to fly for some applicants. However, it is very likely that the majority joined because of the ethos that the RAF projected.[72] This ethos, nonetheless, was essentially based around 'fighter pilots'. Despite the fact that most pilots and aircrew flew aircraft other than fighters, the impression was, and, to a certain extent, remains today, that the RAF is made up of fighter pilots. In reality, this has never been the case. As of 2011, the RAF's total fulltime strength was approximately 36,500 personnel.[73] As an example of the number of front-line fighter pilots from this total, in 2011 the RAF's operational Typhoon strength numbered 36 frontline aircraft. Traditionally, the RAF has 1.5 times the number of pilots for each frontline aircraft. This gives approximate operational total fighter pilot strength of 54.[74] This example is not intended as definitive, but it is not many out of 36,500. It does, however, illustrate that it is only a small portion of current RAF personnel that actually fly. The vast majority are support personnel, which include aircraft engineers, avionics technicians, administrators, logistics personnel, medical professionals, caterers and physical education staff. This list is not exhaustive, but it is likely to be similar to that of most other air forces around the world.

If the RAF, or the UK military establishment, does become autonomous unmanned systems centric, or even semi-autonomous, the recruitment of personnel to conduct the roles required to operate and manage these systems will need to be tailored to ensure that the

[71] For an example of the importance that groundcrew played during World War II, see Richard J. Overy, *The Air War: 1939-1945,* Washington, DC: Potomac Books Inc., 2005, pp.140-141.

[72] For a view on the background to the emergence of aircrew ethos in the RAF, see Dr Peter Lee, 'Remoteness, Risk and Aircrew Ethos', *Air Power Review* 15, no. 1, 2012, pp.2-8.

[73] Approximate figure as of 2011-2012, see 'The Management of Defence: Defence Personnel Totals', *armedforces.co.uk*, http://www.armedforces.co.uk/mod/listings/l0013.html, (accessed 5 January 2012).

[74] No 29 Squadron, the RAF's Typhoon Operational Conversion Unit, has approximately 15 aircraft and instructor pilots. Although these pilots could be utilised, they are considered to be Limited Combat Ready - see Amyas Morse - Comptroller and Auditor General, National Audit Office, *Management of the Typhoon Project*, London: The Stationery Office, 2011, http://www.official-documents.gov.uk/document/hc1011/hc07/0755/0755.pdf, (accessed 12 January 2012).

most suitable personnel were motivated to join the Services.[75] What will be the character of these personnel? What intellectual qualities will be required? Will the whole ethos of the RAF change, and if so, will it matter? The questionnaire asked: 'Would a predominance of UCAS being an air force's combat strength in 2040 affect the motivation for personnel wanting to join?' The majority, 82%, do not believe recruitment will be affected, there will just be a different motivation; indeed, there is an underlying opinion that recruitment, while attracting a different type of person, could be enhanced. Future personnel would be attracted by the technology driven role of an air force. Some interviewees opined that, while recruiting could be affected initially, overtime, perceptions would change, to the extent that it would not be a significant factor. Nine percent had minor issues, which included some concern over the 'fighter ethos' being eroded. A small number, 9%, expressed major issues. One of the three students interviewed expressed concern with motivation. ACM Dalton considers that recruitment would be affected initially, but perceptions would change. '[The] experience of Reaper [UAS] is that there is no shortage of volunteers.' AM Nickols believes that motivation would change, but not necessarily negatively, '…they [the recruits] would just be different'. ACM Torpy simply states there would be no issues. ACM Bryant considers that, 'Personnel would be motivated by different things. [They] would not be the same type of personnel joining today, although not exclusively. If people can be motivated to join to 'serve', [for example] engineers, then there are probably enough people interested'. A retired air marshal, previously responsible for Information Superiority policy for the MOD, believes it will be a different type of person joining. He also asked, 'Why an RAF?'[76] Major General Wells believes it would increase recruiting, '…as it "opens up" the rather restricted criteria for employing fighter aircraft in combat'. Flight Lieutenant Skinner, the Typhoon pilot, believes recruitment would be improved –'If we were at the forefront of this technology it would be very appealing'.

Those with major apprehensions on future motivation to join offer a cogent argument for concern. These opinions are in the minority however, with 91% having no or only minor issues. Nonetheless, the concerns are warranted, particularly that of the skill of tactical leadership being lost. How this will be addressed will test the development of UCAS, and those skills required to put into operation doctrine that is currently gained over years of experience by commanders, all of whom are aircrew, who have many years operational and flying experience. Overall, there seemed to be very few issues regarding the future motivation of personnel wanting to join an air force. The general view is that future

[75] For an insight into the cultural and ethical issues concerning the RAF's use of UAS, see Seb Cox, 'Unmanned Aerial Vehicles - Cultural Issues', in *Air Power - UAVs: The Wider Context,* Owen Barnes (ed), RAF Northolt: RAF Directorate of Defence Studies, 2009, pp.86-96.

[76] Interviewed under the Chatham House Rule - 6 January 2011.

generations will be more inclined to find the computer orientated tasks more fulfilling. Professor Phillip Sabin makes an interesting observation: 'The challenge for airmen and airwomen is to move away from the flight experience itself as the defining qualification for air leaders, and to build a more enduring identity around expert employment of the distinctive strategic characteristics of air, space and cyber capabilities'.[77] This view will certainly have traction if air forces become unmanned centric. Dr Peter Lee probably best captures the reality of UAS operators' and ethos: 'It is the moral courage, combined with a determination to protect allied troops and kill enemy combatants while going to great lengths to avoid the unnecessary deaths of noncombatants that already provides, and will increasingly provide, the basis for RPAS aircrew ethos'.[78] Lee's opinion captures the holistic belief that the ethos of the RAF includes all personnel, not just the 'flyers'.[79] The USAF has recognised the importance of motivation and ethos, and is developing recruitment structures and incentives for UAS personnel, with plans to operate UAS units in a similar way to manned aircraft units. New professional fields have been established, aiming to integrate senior operators into the command structure, as they progress through their careers.[80]

Is the Manned Fighter Necessary and Could UCAS Gain Control of the Air in 2040?

The main purpose of the questionnaire was to garner views on whether a manned fighter was necessary, or if a UCAS could perform the full gamut of combat air tasks by 2040. Two questions were asked – both similar. 'Will it be crucial to have a pilot in the cockpit, or will a semi-autonomous UCAS, or fully autonomous UCAS, be able to gain control of the air, in 2040?' Also, 'Would a UCAS be able to effectively conduct counter-air missions in 2040?' These two slightly different questions were asked to establish whether there was consistency in opinion, if the term pilot was introduced into a question.

In response to the first question, 67% believe there is no requirement to have a pilot in the cockpit, with 22% believing there is no requirement, but with caveats. The caveats include views that situational awareness must be such that it allows for these types of systems to operate autonomously, within the LOAC. AM Nickols believes it will be preferable to have UCAS. ACM Torpy believes, '…a swarm of UCAS should be controlled by a piloted

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[77] Professor Phillip Sabin, 'The Current and Future Utility of Air and Space Power', *Air Power Review* 13, no. 3, 2010, p.168.

[78] Dr Peter Lee, *op. cit.,* p.15.

[79] See generally, Royal Air Force, *AP 1: Ethos, Core Values and Standards*, Director Personnel & Training Strategy, 2008.

[80] See *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047*, pp.28-29, and 59.

aircraft, and we will be reliant on the degree we can progress AI'.[81] ACM Dalton does not believe piloted counter-air will be required, 'But it depends on the scenario…[and the] limitations of commanders and politicians to use [these] systems'. ACM Bryant considers that it will not be crucial, but manned aircraft will be part of the matrix. Overall, 10% believe a pilot will be required, with 1% not sure. The response to the second question resulted in 65% stating a UCAS could conduct counter-air missions effectively, with 33% believing the system could, but with caveats. Overall, 98% believe a UCAS could conduct counter-air missions, with 1% stating no, and 1% not sure. Senior commanders' views are worth highlighting: ACM Torpy believes UCAS could, as do ACM Bryant and AM Nickols. ACM Dalton sees no reason, in principle, why UCAS could not effectively conduct counter-air missions; it will rely on sensors, both off- and on-board, and NEC. Major General Wells, states, 'Yes, but with caveat. We need a man-in-the-loop. This is the future'. Flight Lieutenant Skinner, our archetype junior fighter pilot, simply states: '…UCAS will be effective counter-air systems and that pilots will not be required by 2040'.

Summary

This is a relatively short summary of interviewee responses, as in general, the answers were either yes or no. A large proportion of the interviewees are knowledgeable about air power, both in theory and practice; others are experts in the technological aspects of counter-air warfare. While not providing proof that a UCAS could conduct all counter-air roles by 2040, the responses support the hypothesis that it is at least worth investigating the potential for UCAS that are capable of gaining control of the air. Ethical and legal issues also require some thought, however, it is evident from the responses to the questionnaire, that there is little compunction against their use, if the LOAC is adhered to. Likewise, recruitment concerns do not appear to be thought a major issue, for the moment, at least.

Ultimately, examination of expert opinion and technological capabilities, aligned with a review of international relations, and analysis of the questionnaire, have informed the findings of this thesis. The following chapters examine these issues in depth.

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[81] See Singer, *Wired for War,* pp.229-234. Akin to a flock of birds, it is envisaged that a number of UAS/UCAS could work together, each helping the other to achieve the task. Each system would be given its mission, but able to react to changing environments, taking over part of another systems role, when required - see Dr Howard Tripp and Daniel Page, 'The Perfect Swarm?', *Aerospace International*, July 2012, pp.20-21.

Chapter 2: Overview

This chapter gives an outline of the potential that UCAS may offer to military commanders and political leaders in the coming decades. It also gives a brief history of UAS and a synopsis of the issues that are currently being debated regarding UAS/UCAS utility and the environment in which they might operate. Subsequent chapters examine some of these issues in greater depth.

Terminology

The term UAS itself is often misunderstood. Many 'experts' refer to the air vehicle component of a UAS as a 'drone'. This is a legacy term, more fitting to the German World War II V-I Doodlebug, or target drones used for gunnery practice. V-1s were designed to impact a target, and not to be recoverable; they were effectively cruise missiles. Herein lays the problem when defining what in fact, a UAV is. A UAV is not a cruise missile. A UAV is a UA designed to be reusable. A cruise missile has a one-way mission. The Office of the US Secretary of Defense's *Unmanned Aircraft System Roadmap: 2005 – 2030* describes UAV as:

> A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles.[82]

While there is no internationally agreed policy regarding UAS terminology, there are a number of working agreements that attempt to align common lexicon, as far as is possible. The UK's MOD *Joint Doctrine Note 2/11 Unmanned Aircraft Systems: Terminology, Definitions and Classification* aims to be consistent with NATO doctrine.[83] This document offers guidance on the use of common terminology. Nevertheless, it needs to be understood that the terms used in this Joint Doctrine Note are guidance only. The terms Remotely Piloted Air System (RPAS) and Remotely Piloted Aircraft (RPA) have been adopted by the RAF and USAF.[84] It is not the aim of this thesis to argue what terminology should be used. However, there is no consistency at all within the wider military and academic community; even the term UAV seems to evade a consistent definition, with a

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[82] *Unmanned Aircraft Systems Roadmap: 2005 - 2030,* p.1.

[83] Development, Concept and Doctrine Centre, *Joint Doctrine Note 2/11: Unmanned Aircraft Systems: Terminology, Definitions and Classification*, Shrivenham: Development Concept and Doctrine Centre, 2011, pp.2-1 and Annex: Lexicon 2-3. Also see, Joint Air Power Competence Centre, *Strategic Concept of Employment for Unmanned Aircraft Systems in NATO,* Kalkar: NATO, 2010, p.D-4.

[84] United States Air Force Scientific Advisory Board, *Operating Next-Generation Remotely Piloted Aircraft for Irregualr Warfare*, HQ USAF/SB, Washington: 2011, http://info.publicintelligence.net/USAF-RemoteIrregularWarfare.pdf, (accessed 2 February 2012), p.29.

recent RAF CAS referring to a UAV as an Uninhabited Air Vehicle, while another senior RAF officer using the term Unmanned Air Vehicle.[85] None of these terms are incorrect, however, consistency is important.

UAS Historical Background and Developments

The history of the development of UAV is as old as manned flight itself. The subject is thoroughly examined, *inter alia*, in *Air Power – UAVs: The Wider Context.*[86] A brief background is given here, as it is important to understand the progress of early UAV developments, which have informed the evolution of UAS and UCAS programmes.[87] It can be argued that the first UAV utilised were balloons. Indeed, there are examples of unmanned balloons being used to deliver weapons recorded as far back as 1849, when the Austrians besieged Venice launching the first recorded air raids in history.[88] This was a precursor to the horror that massed bombing raids would bring to the civilian population in World War II. The First World War witnessed the development of the first UA for the purpose of attack, with the US, Britain and Germany developing UA, with varying degrees of success. An example is the US Kettering Aerial Torpedo; the Kettering Bug was a small biplane made of wood, equipped to carry a bomb load equal to its own weight, approximately 300 pounds.[89]

The years between the two World Wars saw a decline in UA developments, until 1935, when the British Queen Bee, the first returnable and reusable UAV, was designed for use as an aerial target for training missions. The Queen Bee was radio-controlled and able to fly up to 17,000 ft., with a range of 300 miles, at over 100 mph.[90] World War II witnessed the massive use of air power to deliver effect. Many tens of thousands of airmen from all sides were killed, particularly on bombing missions against heavily defended targets. The desire to protect aircrew led to a US bomber aircraft flown by a crew for part of a mission, when the crew bailed out, and the unmanned aircraft continued to its target.[91] These UA

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[85] Air Chief Marshal Sir Glen Torpy, 'Foreword', in *Air Power - UAVs: The Wider Context*, Owen Barnes (ed), Shrivenham: Directorate of Defence Studies, 2009, p.2.

[86] See Dr Christina J. M. Goulter, 'The Development of UAVs and UCAVs: The Early Years, in *ibid.,* pp.11-24. See also, Anthony Finn and Steve Scheding, *Developments and Challenges for Autonomous Unmanned Vehicles*, Berlin: Springer, 2009, pp.9-11, and 15-24.

[87] For a review of the characteristics of all types of UAS, from micro to large, see R. Austin, *Unmanned Aircraft Systems: UAVs Design, Development and Deployment*, Chichester: John Wiley & Sons Ltd, 2010, pp.45-74.

[88] Brett Holman, 'The First Air Bomb: Venice, 15 July 1849', http://airminded.org/2009/08/22/the-first-air-bomb-venice-15-july-1849/, (accessed 3 November 2010).

[89] Charles Jarnot, 'History', in *Introduction to Unmanned Aircraft Systems,* Richard Barnhart and others (eds), London: CRC Press, 2012, p.4.

[90] *ibid.*, p.6.

[91] Thomas P. Ehrhard, *Air Force UAVs: The Secret History*, Arlington: Mitchell Institute Press, 2010, p.2.

were not particularly successful, and are not considered UAV, within the context of this thesis.

Reconnaissance missions have always been dangerous. The *Unmanned Aircraft Systems Roadmap: 2005 – 2030,* observes that during World War II, 25% of the 3rd Reconnaissance Group's pilots were lost in the North African campaign, compared to 5% of bomber crews flying over Germany.[92] When the Soviet Union shot down a U-2 reconnaissance aircraft and captured its pilot on 1 May 1960, manned flights over the Soviet Union ceased. This U-2 and its pilot, Frances Gary Powers, was only one of 23 manned aircraft and 179 airmen lost on Cold War reconnaissance missions; their loss spurred the USAF to develop UA for these missions.[93] The US developed a number of highly classified, at the time, UAS capable of conducting long-range reconnaissance missions into hostile territory; the AQM-34 Firebee and Lockheed D-21 being the prime examples.[94]

In 1960, the USAF began its first stealth aircraft programme and began to modify combat UAV for reconnaissance missions, and the resultant AQM-34 Ryan Firebee, still in US service as late as 2003, was air-launched and controlled from a DC-130 director aircraft. After a mission, the Firebee UAV was directed to a safe recovery area, where it deployed its parachute and was then recovered. The Firebee proved extremely successful. From October 1964 to April 1975, more than 1,000 AQM-34s flew in excess of 34,000 operational surveillance missions over Southeast Asia. They were deployed from Japan, South Vietnam, and Thailand, flying day and night surveillance, leaflet-dropping, and surface-to-air missile radar detection missions over North Vietnam and other areas of interest.[95] Following the shoot down of an EC-121 SIGINT aircraft by the North Koreans in 1968, with the loss of all 31 aircrew, a SIGINT variant of the Firebee, the 147TE, was developed. These were used to collect SIGINT from North Korea, China and the Soviet Union.[96] The Israeli military were particularly impressed with the Firebee, procuring 12 systems, which they subsequently weaponised. Designated the Firebee 1241, these performed a significant role in the 1973 Yom Kippur War between Israel, Egypt, and Syria, both as reconnaissance UAV and as decoys. On the second day of the war, the Israeli Air Force deployed their Firebees to lead attacks against Egyptian air defences along the Suez Canal. The Egyptians fired their entire stock of SAM at the Firebees, which successfully

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[92] *Unmanned Aircraft Systems Roadmap: 2005 - 2030*, p.2.

[93] *ibid*.

[94] *ibid*., p.2. See also, Yenne, *op. cit.,* pp.25-33.

[95] Ehrhard, *op. cit.,* p.6.

[96] *ibid*. p.12.

evaded most of these missiles, while aiding destruction of a significant number of SAM systems.[97] This marked a new dawn for the utility of UAS, and similar systems, where, perhaps, the utility of which had not been previously investigated, by some nations at least. China may be the exception to this. Swarming of UAV in order to swamp an adversary's air defence systems, to destroy it, reduce its stock of weapons, or mask other raids, is a tactic well worth developing. China certainly has this as a doctrine.[98] During the 1982 Bekaa Valley conflict between Israel and Syria, Israeli UAS were used to great effect, detecting and acting as decoy, helping the IAF to destroy or use EA against the majority of Syrian SAM systems.[99]

The first US UAV shot down over China on 15 November 1964 was revealed as a deliberate attempt by the US to exercise Chinese air defences to collect intelligence on aircraft intercept methods. The US was very keen to gather information on the development of a Chinese nuclear reactor at Lop Nor, requiring a round trip of 4000 nm from Taiwan, for any asset undertaking a recce task.[100] At that time the U-2 was the only aircraft capable of the task. However, with the introduction of Soviet SA-2 SAM systems, these missions became very dangerous, with five U-2 shot down within a relatively short period; these shoot downs led to the development of the D-21 unmanned system. The D-21 was designed to cruise at Mach 4 and at 100,000 ft.[101] Once its mission was complete, the D-21 would drop its wet film in a container into the sea, before self-destructing. Although at the cutting edge of technology at the time, the D-21 was not a success. A disaster during a test flight, leading to the loss of an A-12 (a CIA version of the SR-71) – the D-21's mother launching aircraft – and one of its crew, set the programme back considerably. However, the requirement to be able to fly an unmanned system over China's nuclear weapon testing facilities was deemed so vital that the programme continued. Eventually, it was deployed on missions to overfly targets in China on four occasions, none of which were successful.[102] Ultimately, aircraft such as the manned SR-71 and the unmanned D-21 were retired, with satellite systems filling the requirement. Satellites are not omnipresent, however, and do not obviate the requirement for loitering surveillance.

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[97] Yenne, *op. cit.,* p.29.

[98] Library of Congress Federal Research Division, *Mini, Micro, and Swarming Unmanned Aerial Vehicles: A Baseline Study*, Washington, DC: Library of Congress, 2006, p.30.

[99] Rebecca Grant, 'The Bekaa Valley War', *Air Force Magazine* 85, no. 6, June 2002, pp.60-62.

[100] Ehrhard,*op. cit.,* p.9.

[101] *ibid.*

[102] *ibid*., p.10.

There seemed to be a hiatus with US UAS development from the Vietnam era, until the beginning of the 1990s.[103] While this is not quite the case, it was not until the early 1990s that a coherent programme became successful – the RQ-1A Predator. Predator was the first UAS to use Global Positioning System (GPS) for navigation, as well the first to effectively operate beyond line-of-sight (BLOS).[104] Although there were teething problems, early use of the Predator in Bosnia in 1995 proved its utility. Further successful deployments in Kosovo and Iraq caused the USAF to take the issue of UAS seriously.[105] The MQ-9 Reaper has been developed from the RQ-1A, and is the mainstay ISTAR asset of US and UK UAS operations in current expeditionary warfare. Designed from the outset as a weaponised UAS, Reaper has set the bar for all systems of this type.[106] The requirement for a High-Altitude Long-Endurance (HALE) UAS led to the development of the RQ-4A Global Hawk, designed to fly up to 65,000 ft., with a payload of 2000 lbs., at a range in excess of 3000 nm, and loiter for more than 20 hours.[107] It was far from a straightforward process, however. As part of the Advanced Airborne Reconnaissance System (AARS) programme, Global Hawk was developed at the same time as the Lockheed Martin *DarkStar*. Meant to be complementary to each other, the two projects ended up competing for funding. The prototype *DarkStar* crashed in 1996, effectively ending its development, leaving the Global Hawk as the remaining part of the AARS programme.[108] Ultimately, however, the Global Hawk will only remain sustainable if it can conduct the tasks of the venerable U2.

The US has been at the forefront of current advanced UAS development, with Israel another. Israel began to develop its own UAS during the 1960s and 1970s. The Heron HALE UAS, for example, has been exported to Canada, Australia and India, amongst others. Israel will likely continue to be at the forefront of UAS development.[109] Many other countries have developed UAS. South Africa, China, Russia, Britain, France, Germany, and Italy, all have advanced UAS programmes.[110] Even Iran produces UAS, some copied from other countries' inventories. Most of these countries also strive to market their own systems. For example, the Thales UK *Watchkeeper* ISTAR UAS, a derivative of the Israeli

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[103] Yenne, *op. cit.,* p.35.

[104] Ehrhard, *op. cit.,* p.49. See also, Mark Daly (ed), *Jane's Unmanned Aerial Vehicles and Targets*, Edition Thirty-seven, Coulsdon: IHS Jane's, 2011, pp.327-330.

[105] Ehrhard, *op. cit.,* p.49.

[106] Daly, *op. cit.,* pp.332-335. The designation 'RQ' denotes a reconnaissance role, while 'MQ' denotes a multi-mission, weaponised role – *ibid.,* p.327.

[107] *ibid.,* pp.376-374.

[108] Ehrhard, *op. cit.,* pp.53-55.

[109] Daly, *op. cit.,* pp.131-134.

[110] See generally, Daly, *op. cit.*

Hermes 450 UAS, originally due in service in 2012, but now delayed, will be an important system, working as a short- to medium-range support, within a mix of manned and unmanned ISTAR systems.[111] Current focus is on a replacement for the MQ-9 Reaper UAS. Project *Scavenger* was a study conducted by the UK MOD with the aim of selecting a UAS design in 2012. *Scavenger* is a sub-element of a wider ISTAR project, now known as Project *Solomon*, but previously entitled Project *Dabinett*, which is intended to improve the analysis and dissemination of intelligence.[112] No design was selected from Project *Scavenger.* BAE Systems submitted their Mantis UAS as a solution, with other companies offering their systems, with France's EADS actively canvassing for UK collaboration with its *Talarion* UAS. In late 2011, a Memorandum of Understanding was signed between France and the UK, with the intent that the two countries should collaborate on a UAS project. This is currently referred to as *Telemos*; the programme is a joint venture between Dassault and BAES.[113]

In the last decade, China has closed the gap in UAS development. China now has UAS that are comparable, although not equal to, the US Predator and Global Hawk.[114] The Chinese government has encouraged UAS development, with several companies currently offering over 25 different UAS.[115] China vigorously markets most of its UAS at its own and international air shows. The potential for China to influence the balance of the global arms market is becoming significant - China's Defence industry is booming.[116] During the 1980s and early 1990s, China was among the world's leading weapon suppliers to developing countries; it stumbled during the mid-1990s, unable to compete in the international market place. However, as its defence industry seeks to reduce the PLA's dependence on Russian weapon systems, it is also looking to become a major exporter again.[117] An example of China's continuing push into the international arms market is its showing at the 8th China International Aviation and Aerospace Exhibition in 2010. A number of UAS were displayed, including the *Pterodactyl*, similar to the US Predator-B, and the *BZK-005* and the *Yilong* Medium-Altitude Long Endurance (MALE) UAS.[118] These are thought to be close to

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111 *ibid.,* pp.278-279.

112 *ibid.,* p.8.

113 See Unmanned Aerial Vehicles (UAV) - Dassault Aviation, '2011 Key Figures', 2011, http://www.dassault-aviation.com/en/aviation/group/activities/2011-key-figures.html?L=1, (accessed 14 December 2011).

114 L.C. Russell-Hsiao, 'Advances in China's UCAV Program', *China Brief - The Jamestown Foundation* Vol X, no. 19, 2010, pp.1-2.

115 *ibid.*

116 Timothy Hu, 'A Morning Star Shines', *Jane's Defence Weekly*, 30 July 2008, p.29.

117 *ibid.*

118 Daly, *op. cit.,* pp.32 and 35.

reaching an operational capability. These systems will have the range and endurance to patrol the South China Sea, and further afield.[119] These, and other UAS, are clearly being marketed to foreign militaries. A report to the US Congress by the US-China Economic and Security Review Commission noted that, 'Beijing is developing a "variety of medium- and high-altitude long-endurance" UAVs that include "options for long-range reconnaissance and strike" mission'.[120] China is intent on capturing some of the huge potential emerging markets for weapons and supporting systems.

Following the 2008 Georgian conflict, the Russian military stressed the need to provide its Armed Forces with advanced means of battlefield reconnaissance, when the effectiveness of Russian military operations was severely hampered by the lack of reliable intelligence.[121] Witnessing the success of Georgia's own UAS, predominantly of Israeli origin, led Russia to approach Israel directly for assistance. In October 2010, Israel Aerospace Industries Ltd signed a $400 million contract to sell UAS to Russia.[122] The primary reason for procurement of UAS from Israel is because Russia does not have a particularly coherent UAS programme. Although Russia's aviation industry is capable of producing very sophisticated and capable military and civilian aircraft, it has not, until recently, focused on the development of UAS.[123]

UCAS Background

UCAS may eventually be capable of the full gamut of air missions, including: ISTAR, Air-to-Air Refuelling (AAR), perhaps even autonomous AAR from one UCAV to another UCAV, Strike Control and Reconnaissance, Close Air Support, SEAD, interdiction, EA and conceivably, control of the air in its entirety, including Defensive Counter Air (DCA) and Offensive Counter Air (OCA) missions.[124] One of the greatest advantages UCAS can have is a small radar-cross-section (RCS), if low observable (LO) technology is used.[125] UCAS

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[119] Wendell Minnick, 'China Developing Armed, Recon UAVs', *DefenseNews*, 29 November 2010, p.6.

[120] *ibid.,* p.6. For descriptions of current developments, see also Daly, *op. cit.,* pp.31-46.

[121] 'Russian Company Develops Heavy UAV for Military Use', *Defence Talk: Global Defense & Military Portal - RIA NOVOSTI*, http://www.defencetalk.com/russian-company-develops-heavy-uav-for-military-use-20919/, (accessed 19 October 2010).

[122] Daly, *op. cit.,* pp.8-9.

[123] 'Initial UAV Deliveries to Russia; Pilot Training', *Defense Industry Daily*, 18 January 2011, http://www.defenseindustrydaily.com/Israel-and-Russia-in-UAV-Deal-05459/, (accessed 4 February 2011).

[124] See *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047*, p.34.

[125] Radar is fundamental to the operation of current air defence systems. For an excellent overview of radar system principles, for the non-specialist, see Martin Streetly, *Jane's Radar and Electronic Warfare Systems: 2010 - 2011*, Twenty-second Edition, Coulsdon: IHS Jane's, 2010, pp.3-6. For a more comprehensive understanding of radar principles, see generally, George W. Stimson, *Introduction to Airborne Radar*, El Segundo, CA: Hughes Aircraft Corporation, 1983.

could have long endurance, enabling persistence and availability, and with no aircrew, allowing operations in a toxic environment. Mitigating the effects on aircrew may be a partial driver, but it is the potential reduction in procurement and life-cycle costs, and the capability to persist on task for periods currently not capable by manned fighter aircraft, that will be the main reasons for their usage. Human endurance has historically limited fighter sortie duration to approximately 10 hours.[126] A report from the US Department of Defense's (DoD) Defense Advanced Research Projects Agency (DARPA) states: 'a UCAV weapon system has the potential to fully exploit the emerging information revolution and provide advanced airpower with increased tactical deterrence at a fraction of the total life cycle costs of current manned systems'.[127] Ultimately, if UCAS can do the required tasks more cost effectively, and/or superior to that of a manned system, then their development will have justification.

The relatively recent advent of UAS, such as the Predator is now considered an essential part of the utility of air power. However, recent UAS counter-insurgency operations (COIN) in Iraq and Afghanistan have concentrated on ISTAR and Close Air Support capabilities, with ISR missions in the Arabian Gulf. More strategic missions will require attributes that current UAS do not possess. For example, in November 2012, Iranian Su-25 Frogfoot aircraft unsuccessfully attempted to shoot down a US Predator UAS. Subsequent Predator missions have been escorted by US fighters; an Iranian F-4 attempted to engage a Predator in March 2013, but was warned off by a US escorting fighter.[128] This is a classic example of how vulnerable UAS, that are unable to protect themselves, will be in contested airspace. The current perceived view is that strategic UCAS will need to have LO characteristics – this capability is an obvious advantage, and will perhaps be their greatest asset, but it significantly increases the cost of a UCAS, and, while enabling greater penetration of an adversary IADS, also imposes design limitations.[129] Importantly, this very asset will drive counter-LO techniques, potentially mitigating any benefit gained. For

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[126] Robert O. Work and Dr Thomas P. Ehrhard, *The Unmanned Combat Air System Carrier Demonstration Program: A New Dawn for Naval Aviation?,* Washington, DC: Center for Strategic and Budgetary Assessment, 2007, p.27. See also, Singer, *Wired for War,* p.63.

[127] *Unmanned Combat Air Vehicle Advanced Technology Demonstration, Phase 1, Selection Process Document, MDA972-98-R-0003*, Defense Advanced Research Projects Agency, Washington: US Department of Defense, 1998, http://www.fas.org/man/dod-101/sys/ac/docs/ucav-sol.html, (assessed 9 February 2011), Chap, 1.1.

[128] See Michael Winter, 'U.S. Fighters Warn Off Iranian Jet Chasing Spy Drone', *USA Today*, 14 March 2013, http://www.usatoday.com/story/news/world/2013/03/14/iran-jet-chased-us-spy-drone/1988407/, (accessed 14 March 2013).

[129] See Chapter 4 of this thesis for a description of an IADS, and stealth.

example, the development of multi-static and bi-static radars may offer a potential counter to LO technology.[130]

UCAS Developments

Although UAS are capable of conducting ISTAR and strike missions, they are not survivable in highly contested airspace. UCAS, capable of conducting these combat air tasks, while operating with a high degree of survivability, are being developed by the US, UK, France, Russia, China, and other nations. The US Navy's Unmanned Combat Air System – Northrop Grumman's X-47B UCAS-D programme, which has replaced the USAF's Joint-UCAS effort, aims to demonstrate the technical feasibility, military utility and operational value for a networked system UCAS.[131] As part of the overarching UCLASS programme, the X-47B first flew in 2011, with trials from carriers beginning in 2013, and an anticipated in-service date of 2020.[132] The UCLASS programme was instigated by the Deputy Chief of Naval Operations for Information Dominance. The US navy has identified a requirement, '…for an aircraft carrier based aircraft system providing persistent Intelligence, Surveillance, and Reconnaissance (ISR) and strike capabilities that will enhance the versatility provided by an aircraft carrier…'.[133]

Already mentioned, the UK is developing the *Taranis*, a UCAS demonstrator, while a European consortium is developing the *Neuron* system.[134] Russia unveiled the *Skat* UCAV at the 2007 MAKS Air Show, and although not much was heard of it again until 2011, Russian aircraft manufacturers, MiG and Suhkoi announced in 2011 that they will be working jointly on the *Skat*.[135] China is also known to have its own UCAS programme, the *An Jian (Dark Sword)*, which has been shown as a mock-up at the 2006 Zukhai Air

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[130] See Nick Smith, 'Taking Radar to Another Level', *The Institution of Engineering and Technology*, March 2013, pp.10-13.

[131] For an overview of the UCAS-D programme, see Work and Ehrhard, *op. cit.,* pp.32-39.

[132] See Guy Norris, 'Northrop UCAS-D Completes First Flight', *Aviation Week*, 7 February 2011, http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=defense&id=news/awx/2011/02/04/awx_02_04_2011_p0-287709.xml&headline=Northrop%20UCAS-D%20Completes%20First%20Flight, (accessed 9 February 2011).

[133] Naval Air Systems Command, 'Aircraft and Weapons: Unmanned Carrier Launched Airborne Surveillance and Strike System', http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=A1DA3766-1A6D-4AEA-B462-F91FE43181AF, (accessed 11 February 2011). In March 2013, the USN announced its intention to fund four companies to design UCAS as part of its UCLASS programme. A selection is likely in 2016 - see Zach Rosenberg, 'US Navy Plans to Place Four UCLASS Development Contracts', *Flightglobal*, 26 March 2013, http://www.flightglobal.com/news/articles/us-navy-plans-to-place-four-uclass-development-contracts-383924/, (accessed 3 April 2013).

[134] Daly, *op. cit.,* p.8.

[135] *ibid.,* pp.203-204.

Show.[136] These systems will likely begin to enter the service of these nations in the 2020 – 2025 epoch.[137]

The fundamental understanding of the components that comprise a UCAS, and the types of roles that these systems may be able to undertake, is essential when attempting to analyse any utility that these weapon systems may have in future warfare. Current UAS are not survivable in contested airspace, against an adversary with a sophisticated IADS. Potential future conflicts and the development of UCAS are changing this emphasis. Currently, strategic UCAS are being developed that have stealth characteristics, in both the IR and RF spectrums, and while enabling greater penetration of enemy defences, also imposes design limitations. Significantly, a UCAS will not be stealthy in all RF spectrums. Older Very High frequency (VHF) search radars, updated with the latest computing hardware and software, are able to detect current platforms, such as the US F-22 Raptor. Although the range at which these are detected is still somewhat less than that of third or fourth generation, non-stealthy aircraft, it may be enough to direct counter-air assets to intercept and destroy any hostile aircraft.[138] Open source material is available which highlights the significant advances that the Russians and Chinese have made, particularly in the areas of IADS and counter-stealth technology.[139] The requirement to analyse these capabilities is central to understanding the requirements that UCAS will need in order to dominate the airspace in future warfare. China’s naval expansion is also causing concern. These types of ‘arms races’ mean that there may be a need for changes to tactical concepts, if technology cannot keep pace.[140]

Future Threat Environment

Historically, for every new military capability established by nation-states, their potential enemies will inevitably attempt to counter any such advantage. Predicting future wars is impossible, and as Clausewitz observed, ‘No other human activity is so continuously or

[136] Nicolas von Kospoth, 'China's Leap in Unmanned Aircraft Development', *defpro.daily*, 14 October 2009, http://www.defpro.com/daily/details/424/, (accessed 5 January 2010).

[137] Russian Unmanned Vehicle Systems Association, 'China Developing Armed/Recon UAVs', http://en.ruvsa.com/reports/china_developing_armed_recon_uavs/, (accessed 24 March 2012).

[138] For a description of how passive detection systems can be used to cue fighters and SAM, see Arend G. Westra, 'Radar Versus Stealth: Passive Radar and the Future of U.S. Military Power', *Joint Forces Quarterly*, no. 55, 2009, pp.139-141.

[139] For analysis of stealth technolgies, see Dr Carlo Kopp, 'Russian/PLA Low Band Surveillance Radars: Counter Low Observable Technology Radars', *Air Power Australia* (2009), http://www.ausairpower.net/APA-Rus-Low-Band-Radars.html, (accessed 17 March 2009).

[140] Geoffrey Till explores the possibility of an arms race developing between China, Japan, India and the US – see generally, Geoffrey Till, *Asia's Naval Expansion: An Arms Race in the Making?*, Adelphi Series, London: IISS, 2012.

universally bound up with chance'.[141] It is axiomatic, however, that there will always be potential threats; identification of such threats and their resources is continually analysed by government agencies and policy institutions. At some point, it becomes necessary to make certain assumptions; these will then drive governments' defence procurement and scientific development policies. Some developing nations are on the brink of economically entering the developed world; all seek access to the raw resources that stimulate development. The West's current focus is on irregular warfare; while this type of conflict is likely to be on-going for some time, possibly indefinitely, circumstances may drive nations to believe that the only way to survive, let alone prosper, is to instigate conflict, in order to establish dominance over natural resources. A lack of natural resources, whether for manufacture or sustenance may prove crucial. A resurgent Russia, or an economically powerful and resource-hungry China, aiming to establish hegemony within their spheres of influence, may dictate future governments' defence policies.[142] Not least, containing Iran's nuclear ambitions will continue to test international relations. How will these threats be countered? Will the character and nature of warfare, forcing operations over long distances be such that UCAS are the only viable solution?

Technologies

This thesis is not UK centric, and the likelihood of a direct military air threat to the UK mainland re-emerging from Russia, for example, is minimal.[143] However, threat systems continue to evolve, and potentially hostile regimes are able to obtain sophisticated military hardware relatively easily. Identification of these potential adversaries can be readily determined. It should also be possible to estimate the extent of their capabilities. How they are deterred, and if required, defeated, is not so easily achieved. While not a direct danger to the UK, these threats may pose a risk to UK interests. If the UK continues its interventionist foreign and defence policies – and that is a big if – it is most likely within an alliance in which it will fight future wars, invariably US led, or at least greatly subsidised by US expertise and hardware.

The types of systems required to carry out nations' aspirations will depend on a range of scenarios. If range and endurance are required, systems will need to be procured accordingly. In the years before World War II, the US faced choices between procuring

[141] Michael Howard and Peter Paret (eds), *Carl Von Clausewitz: On War,* Princeton, NY: Princeton University Press, 1976, p.85.

[142] For the implications of a resource stressed China, see generally, Dambisa Moyo, *Winner Take All: China's Race for Resources and What It Means for Us,* London: Penguin Group, 2012.

[143] See 'House of Commons Defence Committee - Tenth Report. Russia: A New Confrontation', (2009). http://www.publications.parliament.uk/pa/cm200809/cmselect/cmdfence/276/27602.htm, (accessed 19 July 2011), Chap 2, para 53, and Chap 8, para 211.

more short-range assets, or opting for sea and air systems, with greater range; the latter helped win the war. The US's current and likely future security responsibilities in the Western Pacific offer a similar scenario. An editorial in *DefenseNews* emphasised that: 'The U.S. is shifting its strategic focus to Asia, where allies worry about rapid military rise and increasing assertiveness. Boosting U.S. regional presence is key, but the Pacific is a vast theater and distance is a tyrant'.[144] The types of weapon systems required to meet his challenge will test current doctrine.

The paradigm has shifted. A fundamental rethink is taking place in the way C2 is conducted, and the ways in which military objectives are achieved. Significant advances in capabilities, together with flexibility in force employment and improved efficiency, will result in a vastly increased ability to achieve the desired outcome. It can be argued that technology offers military forces a solution to solving the difficult tactical and operational conundrums posed by future wars. Whether this is correct or not, the dramatic results of recent military operations indicate a major expansion in military capabilities. Advances in a broad range of technologies have begun to enable the integration of joint-forces not previously possible.

Future US air doctrine will be NEC-centric, probably utilising stealth technology as a key enabler.[145] TDL are a fundamental part of NEC; these are utilised by air, sea and land forces, enabling Joint Fires (the delivery of an effect using a combination of platforms and systems, whether ground, sea, air or space borne), particularly by US and UK armed forces. The US F-22 Raptor air supremacy fighter is, currently, the only Western fifth-generation stealth aircraft of its type; indeed, despite rhetoric, no other nation is close to achieving this capability.[146] The F-22 may be very manoeuvrable, indeed superior to any other comparable aircraft; however, the question remains - is this of any significance? If it is not, then what are the prerequisites of a future counter-air aircraft? Is it speed, manoeuvrability and endurance, or is it stealth and NEC, or a combination of these? The importance that EA capabilities and defensive countermeasures have in future air power scenarios will also be of enormous significance. Advances in technology will continue to

[144] Vago Muradian, 'Rethink the Status Quo', *DefenseNews*, 7 November 2011, p. 28

[145] The US use the term Network Centric Warfare (NCW) vice the UK usage of Network Enabled Capabilities. For the origins and development of the concept of NCW, see Paul T. Mitchell, *Network Centric Warfare: Coalition Operations in the Age of US Miltary Primacy*, The International Institute for Strategic Studies: Adelphi Paper 385, Routledge: Abingdon, 2006, pp.28-35. See also, Fran P. B. Osinga, *Science, Strategy and War: The Stragetic Theory of John Boyd*, Abingdon: Routledge, 2007, pp.249-251. The Russians also use the term NCW; for a Russian view on the issues facing the Russian military, see Colonel A. Raskin, Colonel V.Pelyak, and Colonel S. Vyalov, 'Network-Centric Warfare Concept: Pro and Contra', *Military Thought: A Russian Journal of Military Theory and Strategy* 21, no. 3, 2012, pp.8-16.

[146] See Paul Jackson (ed), *op. cit*., pp.788-792.

allow weapon systems to develop, and a 'system of systems' may be capable of achieving the desired effect. An understanding of what might be achievable, and an ability to appreciate the 'art of the possible', is required of a state's military and political commanders. There continues to be a dramatic expansion in computing technology. 'Moore's Law' states that computing processing power doubles approximately every 24 months.[147] This principle has been proven correct, thus far; indeed, the video gaming industry is taking the lead in developing processing capabilities. Understanding the significance of this is vital, with future improvements in processing power potentially increasing in excess of the rate stated by 'Moore's Law'.[148] This expansion in processing power will be crucial for almost all future technological advances.

Aerial Warfare

Most major conflicts since World War II have involved some form of aerial warfare. The Korean War, the Israeli/Arab conflicts of 1967 and 1973, the Vietnam War, the 1982 Israeli/Syrian Bekaa Valley conflict, and the 1982 Falkland's War, involved air-to-air engagements, some of which required aggressive visual manoeuvring in order to engage and kill an adversary, employing either short-range IR AAM or AAG.[149] However, since the 1980s, conflicts such as the 1991 Gulf War, Bosnia and Kosovo, most successful airborne engagements have been conducted BVR with RF AAM, or WVR, with RF and IR AAM.[150] Similar to other munitions, launched at range, BVR AAM are permitted under the LOAC: 'Missiles and other projectiles fired from beyond visual range are lawful when their employment permits distinguishing military objectives and combatants from civilians and civilian objects. Such may be accomplished through sensors on the weapon itself, or through external guidance, for instance from the aircraft'.[151]

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[147] For the background on Moore's Law, see David Brock, 'A Clear Voice: The Origins of Gordon Moores's 1965 Paper', in *Understanding Moores's Law: Four Decades of Innovation,* David Brock and Gordon Moore (eds), Philadelphia, PA: Chemical Heritage Foundation, 2006, pp.25-36.

[148] National Research Council of the National Academies, 'The Rise of Games and High-Peformance Computing for Modeling and Simulation', Chapter 2 - *Modeling, Simulation, Games and Computing*, http://www.nap.edu/openbook.php?record_id=12816&page=10, (accessed 14 October 2011).

[149] See Appendices B-D of this thesis for analysis. Visual range depends on various factors: visual acuity, visual enhancements, visual inhibitors, light conditions, target aspect, and target size. – see Col Patrick Higby USAF, *Promise and Reality: Beyond Visual Range (BVR) Air-to-Air Combat*, Air War College (AWC) Electives Program: Air Power Theory, Doctrine, and Strategy: 1945 - Present, (30 March 2005), http://pogoarchives.org/labyrinth/09/06.pdf, (accessed 17 March 2010), p.4, and Table 1, p.5. Five to ten nautical miles is accepted as a reasonable baseline – see Col James Burton USAF, 'Letting Combat Results Shape the Next Air-to-Air Missiles', (1985), http://pogoarchives.org/labyrinth/11/07.pdf, (accessed 11 August 2012), slide 3.

[150] See analysis at Appendices B – D.

[151] *Commentary on the HPCR Manual on International Law Applicable to Air and Missile Warfare*, p.75.

The US F-35 JSF is being procured as a replacement for the F-16 Fighting Falcon. While it is relatively manoeuvrable, it is not in the same league as the US F-22 Raptor, UK Typhoon, French Rafale or the Russian Su-27 Flanker and MiG-29 OVT Fulcrum fighters. Some military aviation analysts argue that the F-35 will not be able to gain control of the air.[152] A project such as the JSF is highly classified, with much of the information on its capability not available in the public domain. For the moment, let us assume that the JSF is capable of at least defending itself in a high threat environment, against an air superiority platform. It is also entirely possible that JSF itself may be developed or modified to operate unmanned in the future. John Pike, executive director of GlobalSecurity.org, believes, '[It] would be crazy not to be looking at this. It's a foregone conclusion that at some point in the F-35 production program that [the Air Force is] going to decide we're going to replace the rest with unmanned systems'.[153] This raises the question: how much research, development and expense should there be towards an air vehicle, whether manned or unmanned, that is capable of pure 'dog fighting' - that is, highly manoeuvrable, visual air combat? It is arguable whether this ability to out manoeuvre fighters is relevant in an era when long-range BVR AAM capability is of such importance. It is perhaps surprising, therefore, that current Western, Chinese and Russian fighters strive for an ability to obtain a maximum sustained and instantaneous turn performance, the most important attributes for fighters in the visual air combat environment.[154] Why is this? In some low- or mid-intensity conflicts, for example Bosnia in the early 1990s, the ROE required air defence crews to visually identify (VID) any potential target before engagement, thereby potentially forcing that fighter into a visual merge.[155] Moreover, in a high-intensity conflict, when faced with an adversary with capable aircraft and weapons, and training, in which a VID is not required, AAM technology has not always guaranteed that the BVR 'Shoot Out' will succeed.[156] This area is the core question of whether a UCAS could successfully conduct counter-air operations in future warfare.

[152] For example, see Dr Carlo Kopp, 'F-22 Termination: America's Self-Induced Strategic Death Spiral', *Air Power Australia NOTAM* ,14 April 2009, (accessed 1 May 2009). Kopp argues that the F-35 JSF will not be as capable as the F-22 in the air superiority role, and its development requires serious rethinking.

[153] Renae Merle, 'Lockheed Says F-35 Could Fly Pilotless', *Washington Post*, 16 August 2006, http://www.washingtonpost.com/wp-dyn/content/article/2006/08/15/AR2006081501288.html, (accessed 24 May 2009).

[154] For an overview of the importance of fighter aircraft manoeuvrability and turn performance, that is, sustained and instantaneous capability, see Shaw, *op. cit.,* pp.387-392.

[155] An example of this is the US experience during the Vietnam War, see John S. Attinello (ed), *Air-to-Air Encounters in Southeast Asia: Volume IV: Analyses,* Arlington, VA: Institute for Defense Analyses Systems Evaluation Division, 1968, http://www.paperlessarchives.com/FreeTitles/WSEGReport116.PDF, (accessed 14 October 2012), p.8.

[156] See analysis in Chapter 5.

When discussing warfare, it is useful to have an understanding of conflict intensity. Low-intensity conflict (LIC) is defined by the US as:

> …a limited politico-military struggle to achieve political, social, economic, military, or psychological objectives…LIC is generally confined to a geographic area and is often characterized by constraints on weaponry, tactics, and level of violence…[Mid-intensity conflict is]…war between two or more nations and their respective allies, if any, in which the belligerents employ the most modern technology and all resources in intelligence; mobility; firepower (excluding nuclear, chemical, and biological weapons)…for limited objectives as to the extent of destructive power that can be employed or the extent of geographic area that might be involved.[157]

High-intensity conflict is as per mid-intensity, except nuclear, chemical, and biological weapons may be used, and there are no limitations on objectives, or the geographic area involved.[158]

The more advanced an adversary's counter-air capability, the more important gaining and maintaining control of the air, and the more sophisticated a force's own counter-air capabilities requires to be. Having freedom from attack and freedom to attack are the fundamental principles of control of the air. The ability to conduct the full range of air operations, unhindered, against enemy forces is vital; it enables the safe deployment, resupply, and protection of those forces once deployed.[159] This concept of aerial warfare has been validated since World War I. In future warfare, will it be possible for UCAS to conduct these combat roles and accept most of the risks that thus far have been the lot of military aviators, in particular, the counter-air role? Control of the air was quickly gained in Iraq, and in Afghanistan it was essentially a given from the beginning of operations. However, there is a risk of forgetting the lessons of previous conflicts: if control of the air is not gained, a campaign is likely to fail. The Libya campaign of 2011 reinforced the importance of air power, and was an exemplar of how air power, on its own, virtually attained the required outcome.[160] Control of the air was quickly gained by a coalition led by the UK and France, and with a great deal of aid from the US in terms of initial strikes from combat aircraft cruise missiles, and support assets, including intelligence, planning and

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[157] Department of the Army Headquarters, *Intelligence Interrogation*, Washington, DC: HQ TRADOC, 1987, p.9-1.

[158] *ibid.* These terms may be argued as not being relevant, see for example, Christopher Bellamy, 'If You Can't Stand the Heat...New Concepts of Conflict Intensity', *The RUSI Journal* 143, no. 1, 1998, pp.25-31. However, they suffice for the purposes of this thesis, in delineating the ROE processes that pertain to air-to-air warfare.

[159] For an overview on the roles of air and space power, *AP 3002 – Air and Space Warfare, 2nd Edition,* Air Warfare Centre: RAF Waddington, 2009, pp.4-1 to 4-9.

[160] Although naval units, the Army Air Corp, and some personnel were involved on the ground, the weight of effort was conducted by countries' air forces. For a discussion on the air campaign, see Elizabeth Quintana, 'The War from the Air', in *Short War, Long Shadow: The Political and Military Legacies of the 2011 Libya Campaign*, Adrian Johnson and Saqeb Mueen (eds), London: The Royal Unitied Services Institute for Defence and Security Studies, 2012, pp.31–37. See also, Dr Christian F. Anrig, 'Allied Air Power over Libya: A Preliminary Assessment', *Air & Space Power Journal* XXV, December 2011, pp.89-109.

material support, enabling coalition air forces to conduct operations essentially unhindered.[161] It was the destruction of the Libyan IADS and attacks on centres of gravity that enabled the Free Libyan Forces eventually to defeat Gaddafi's forces. Libya's IADS was not an example of a highly-integrated system, however. It was essentially '…obliterated…within 72 hours'.[162] Other potential adversarial states, for example, Syria, Iran, and China, with access to more modern and lethal sensors and weapons, will offer stiffer resistance.[163]

US UAS Roadmaps

Already mentioned, the US has published a number of UAS developmental paths, setting out its vision for the employment of unmanned systems, including ground, sea and air.[164] Two of these official publications are particularly pertinent to UCAS development: the *Unmanned Aircraft Systems Roadmap: 2005 -2030,* published by The Office of the Secretary of Defense, and the *USAF Unmanned Aircraft System Flight Plan 2009 – 2047*. The *Unmanned Aircraft Systems Roadmap* states: '…The overarching goal of this Roadmap is to guide the Department towards a logical, systematic migration of UAS mission capabilities focused on the most urgent warfighter needs'.[165] In 2009, the then Secretary of the USAF, Michael B. Donley, and the USAF Chief of Staff, General Norton Schwartz, signed the *USAF Unmanned Aircraft System Flight Plan 2009 – 2047*. This *Flight Plan* is the USAF's own vision for the development of UAS. It details an 'actionable plan' for UAS/UCAS.[166] It sets out the USAF vision for the implementation of UAS/UCAS into USAF service, out to 2047. It states:

> [UAS] and the effects they provide have emerged as one of the most "in demand" capabilities the USAF provides the Joint Force. The attributes of persistence, endurance, efficiency, and connectivity are proven force multipliers across a spectrum of global Joint military

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[161] Tom Shanker and Eric Schmitt, 'Seeing Limits to 'New' Kind of War in Libya', *The New York Times*, http://www.nytimes.com/2011/10/22/world/africa/nato-war-in-libya-shows-united-states-was-vital-to-toppling-qaddafi.html, (accessed 13 November 2011). The US conducted 99% of all operational airlift, 79% of AAR, 50% of ISR, and 40% of strike missions, see General Norton Schwartz USAF, 'Air Force Contributions to Our Military and Our Nation - Transcript', (2011). http://www.af.mil/information/speeches/speech.asp?id=688, (accessed 1 May 2012).

[162] Ivo H. Daalder and James G. Stavridis, 'NATO's Victory in Libya: The Right Way to Run an Intervention', *Foreign Affairs* 91, no. March/April, 2012, p.3. For a description of the Libyan IADS, see Dr Carlo Kopp, 'The Perfect Fighter: Does It Exist, Do We Need It, Can We Afford It?', *Flight Journal*, no. 16 July 2012, p.46.

[163] Andrew Tilghman, 'Military Leaders Cautious About Plans for Syria Ops', *Air Force,* 2012, p.19. See also, Dr Ayse Abdullah (ed), *The Military Balance*, London: Routledge, 2013, p.14

[164] The USAF, USN, United States Marine Corp (USMC), and US Army have each published their own Unmanned Systems Roadmaps – see *Unmanned Systems Integrated Roadmap FY 2011 - 2036,* pp.1-2.

[165] *Unmanned Aircraft Systems Roadmap: 2005 - 2030*, Signed Memorandum for Secretaries of the Military Departments - first page.

[166] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047*, p.38.

> operations….The vision is the USAF postured to harness increasingly automated, modular, globally connected, and sustainable multi-mission unmanned systems resulting in a leaner, more, adaptable and efficient air force that maximises our contribution to the Joint Force.[167]

The USAF intends, '…to achieve the USAF vision for the future of UAS. The USAF will implement the actions described within to evolve UAS capabilities'.[168] There are a number of assumptions which drive the focus for the USAF's vision, emphasising the attributes of persistence, speed of reaction, potential reduced costs and automation:

> ….Integration of manned and unmanned systems increases capability across the full range of military operations for the Joint fight…UAS are compelling where human physiology limits mission execution (e.g. persistence, speed of reaction, contaminated environment)…Automation with a clear and effective user interface are the keys to increasing effects while potentially reducing cost, forward footprint, and risk…Agile, redundant, interoperable and robust command and control (C2) creates the capability of supervisory control ("man *on* the loop") of UAS…The range, reach, and lethality of 2047 combat operations will necessitate an unmanned system-of-systems to mitigate risk to mission and force, and provide perceive-act line execution...[169]

The *Flight Plan's* emphasis of the man-on-the-loop, and the range, reach and lethality of combat operations requirements, captures a number of fundamental premises of this thesis. Comments in December 2012 by General Mike Hostage, commander of the USAF Air Combat Command, offer an insight into current US thinking on the utility of UAS/UCAS; he gave his view on the applicability of current UAS developments, and what would be required for future high-intensity operations. Speaking to reporters, Hostage stated:

> We are now shifting to a theatre [the Western Pacific] where there is an adversary out there who is going to have a vote on whether I have that staring eye over the battlefield…and [I am] pretty certain they are not going to allow that to happen…The fleet I've built up, and I'm still being prodded to build up too, is not relevant in that new theatre.[170]

Hostage believes that the USAF will have to adjust its force structure to meet the demands of the Pacific theatre. He also said that, '…the USAF has no intention of backing away from the capability unmanned aircraft bring and the "new style of warfare" that they enable'.[171] A prescient point of view, perhaps, or is Hostage merely stating the obvious, that is, the present crop of UAS designs will not survive in the type of scenarios envisaged

[167] *ibid.,* p.3.

[168] *ibid.,* p.14.

[169] *ibid.*

[170] David Mujumdar, 'USAF: Current Unmanned Aircraft Irrelevant in the Pacific', *Flightglobal*. http://www.flightglobal.com/news/articles/usaf-current-unmanned-aircraft-irrelevant-in-the-pacific-379839/, (accessed 17 December 2012).

[171] *ibid.*

in the Western Pacific. General Norton Schwartz, USAF CSAF in 2012, also reiterated that today's UAS cannot survive in contested airspace.[172]

Bringing all of the UAS 'roadmaps and plans' together, is the US DoD's 2011 *Unmanned Systems Integrated Roadmap FY 2011-2036.* Now on its 3rd edition, it was first published in 2007, and has evolved into a document which is focused on the issues facing all US Armed Services, as well as setting out a vision and acting as a single, unified source.[173] This *Roadmap* seeks to establish a unified vision:

> US aircraft procurement plans, out to 2041, detail plans for manned and unmanned acquisitions. The Department of Defense's vision for unmanned systems is the seamless integration of diverse unmanned capabilities that provide flexible options for Joint Warfighters while exploiting the inherent advantages of unmanned technologies, including persistence, size, speed, maneuverability, and reduced risk to human life. DOD envisions unmanned systems seamlessly operating with manned systems while gradually reducing the degree of human control and decision making required for the unmanned portion of the force structure.[174]

The UK MOD seems to be somewhat behind the US in its UAS/UCAS developmental philosophy.[175] Without any substantial UK 'Roadmap', the author has used US 'Roadmaps' and programmes as a reference baseline in this thesis. Although not definitive, all three US Roadmaps/Flight Plans (2005, 2009, and 2011) are used, where appropriate. While there are no equivalent UK UAS Roadmaps in the public domain, one strand of the RAF's recent Deep and Persistent Offensive Capability (DPOC) study, examined the feasibility of UCAS as a replacement for the GR-4 Tornado bomber.[176] When interviewed by the author, ACM Sir Glen Torpy, the Royal Air Force's (RAF) Chief of Air Staff until 2009, now BAE Systems Senior Military Adviser, stated he believed that, due to their potential capabilities and cost benefits, UCAS will become a prominent part of the RAF's inventory.[177] Funded by the UK MOD and BAE Systems, The *Taranis* UCAS programme is a technology risk reduction demonstrator, initially instigated to inform the DPOC process, but now informing the UK's wider UCAS development route.[178] The UK's MOD is also looking at a range of options for its future combat air power; part of the Future Combat Air System (FCAS) programme is a

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172 S. C. Charles, 'Air Force Chief Talks of Shrinking Budgets, Post-Iraq Exhaustion', *National Journal*, 2 May 2012, http://www.nationaljournal.com/nationalsecurity/air-force-chief-talks-of-shrinking-budgets-post-iraq-exhaustion-20120502?mrefid=site_search, (accessed 19 September 2012).

173 See, *Unmanned Systems Integrated Roadmap FY 2011-2036*, pp.1–2.

174 *ibid.,* p.3.

175 For a view on the UK MOD's lack of an overarching UAS vision, see Dr Matt Bassford, 'The UK Lacks a Clear Strategy for Unmanned Aircraft', *Defence Management Journal*, Issue 55: 2012, http://www.defencemanagement.com/article.asp?id=541&content_name=Modernising%20Defence&article=18127, (accessed 14 March 2013).

176 Daly, *op. cit.,* pp.264-265.

177 ACM Sir Glen Torpy RAF, interviewed 11 October 2011.

178 Daly, *op. cit.,* pp.264-265.

France/UK study, which is looking at the potential use of UCAS as a replacement for current manned platforms.[179]

Autonomy or Automation?

The term autonomous is often used when referring to the operation of UAS/UCAS; this has caused some concern among certain sectors of the military and media, with the belief that the use of autonomous UAS would not be acceptable in some scenarios. The debate over the meaning of autonomy is ongoing. The UK's MOD's DCDC, defines an automatic system as: 'A system, in response to one or more sensors, is programmed to logically follow a predefined set of rules in order to provide an outcome. Knowing the set of rules under which it is operating means that its output is predictable'.[180] The Oxford English Dictionary (OED) defines automation as: 'Like the action of an automaton; unintelligent, merely mechanical; done without thought, unconscious; occurring as a matter of course without debate. Working by itself, without direct human involvement'.[181] Autonomy is described by DCDC as: 'A system that is capable of understanding higher intent; will be effective, self-aware and their response to inputs indistinguishable from or superior to, that of a manned aircraft. As such, they must be capable of achieving the same level of situational understanding as a human'. The OED defines autonomy as: 'Freedom of the will. Independence, freedom from external control or influence. Personal liberty. Self-governing. Free to act independently'.[182] Gillespie and West, in *The International C2 Journal,* describe autonomous and automatic systems:

> [autonomous systems]…[as] act[ing] on results from their own processing of instructions from external sources; without necessarily involving human operators after initiation. Automatic systems are directly controlled by either a human or quantified input parameters with no interpretation by the automaton.[183]

A report for the US Office of Naval Research, defines autonomy as: '….the capacity to operate in the real-world environment without any form of external control, once the machine is activated and at least in some areas of operation, for extended periods of

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[179] 'BAE and Dassault Secure Anglo-French FCAS Demonstration Contract', *Airforce-technology.com*. http://www.airforce-technology.com/news/newsbae-dassault-secure-anglo-french-fcas-demonstration-contract, (accessed 12 November 2012).

[180] *Joint Doctrine Note 2/11, Unmanned Aircraft Systems: Terminology, Definitions and Classification,* p.1.5.

[181] Lesley Brown (ed), *Shorter Oxford English Dictionary*, 6th Edition, Vol 1, New York: Oxford University Press Inc, 2007, p.157.

[182] *ibid,* p.158.

[183] Tony Gillespie and Robin West, 'Requirements for Autonomous Unmanned Air Systems Set by Legal Issues', *The International C2 Journal* Vol 4, no. 2, 2010, p.3.

time'.[184] The *Commentary on the HPCR Manual on International Law Applicable to Air and Missile Warfare* defines autonomous UCAV as: 'Autonomous action means that the unmanned aircraft has sensors and an onboard data processing capability to make decisions to attack according to a computer program. The sensors and computer programs must be able to distinguish between military objectives and civilian objects, as well as between civilians and combatants'.[185]

Air Commodore Anthony Nicholson, a former Commandant of the RAF Institute of Aviation Medicine, and in 2012 the Visiting Professor at the Centre for Human and Aerospace Physiological Sciences of Biomedical Sciences, King's College, London, believes that a system that could think like a human, an autonomous system, as described by DCDC, '…would have responsiveness indistinguishable from, if not superior to, that of manned aircraft, levels of situational awareness far beyond those of humans, [and] be able to exercise judgement and possess a sense of responsibility'.[186] Nicholson argues that significant advances would be required for such autonomous air systems, but that 'automated' systems may reach levels of human situational awareness, and my even exceed these. These automated systems, however, will lack the ability to judge and have a sense of responsibility, that is, '….there is no 'awareness of awareness''.[187] This component, Nicholson believes, would be the key to an autonomous system.[188] However, Nicholson believes a truly autonomous system is not currently viable, nor likely to be for some time, stating that: 'The mystery of consciousness will not be solved in this century…It is the increased sophistication of on-board artificial intelligence in unmanned systems, subservient to human decision making, that will be the means by which air capability will be enhanced for the foreseeable future'.[189] All of these views warrant consideration.

It is apparent that within the UK MOD there is no consistent view of what autonomy means in relation to UCAS. Gillespie and West's, and the ONR report's view of autonomy comes closest to the author's vision of UCAS employment, but this is still really only a high level of automation. With automation, DCDC describes '…its output is predictable'.[190] It should be expected that any weapon system's output is predictable, when working correctly.

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[184] See Patrick Lin, George Bekey, and Keith Abney, *Autonomous Military Robotics: Risks, Ethics, and Design,* San Luis Obispo: Ethics and Emerging Sciences Group at California Polytechnic State University, 2008, pp.103-105.

[185] *Commentary on the HPCR Manual on International Law Applicable to Air and Missile Warfare*, p.101.

[186] Air Commodore Anthony Nicholson RAF, 'The Autonomous Air System: Far Beyond the Foreseeable Future', *Aerospace International* 39, no. 10, 2012, p.29.

[187] *ibid.,* p.28.

[188] *ibid*.

[189] *ibid.*, p.29.

[190] *Joint Doctrine Note 2/11, Unmanned Aircraft Systems: Terminology, Definitions and Classification*, p.2-2.

Similarly, a pilot's output should be predictable, as would be UCAS's. Even an adversary's actions should be predictable, within defined boundaries. This is not in the sense that adversaries' actions can be predicted; but it does mean that 'systems' will follow a set of rules, defined within pre-programmed matrices, while manned systems will use tactics and procedures that are constrained by the laws of physics and convention. Unpredictable actions should not be confused with a pilot, for example, who carries out a manoeuvre that allows him to defeat an adversary in air-to-air combat, one that his adversary was not expecting. This manoeuvre would not be invented on the spot; it would be one that was within the pilot's skill-set; one that had been practised - one that would be the best manoeuvre for that situation. It may seem unpredictable to the adversary, but in reality, it is in the bounds of what the pilot and the aircraft could actually do - within the bounds of tactical doctrine and the laws of physics. Strict convention would have been followed to achieve the best result. Manoeuvres made up on the spur of the moment, invariably lead to a suboptimal situation. Major Robert Trsek USAF, (his Master's thesis already mentioned), himself a fighter pilot on F-15Cs, believes automation is the way forward: '…automated BFM can provide far superior maneuvering against the majority of pilots the world over'.[191] It seems that even some UAS autonomy industry experts now acknowledge that what they really mean by an autonomous UAS, is not a truly autonomous system. It was acknowledged at the '2012 Autonomous Systems Technology Related Airborne Evaluation & Assessment Conference', that the UAS industry, '…had not done itself any favours with its choice of [autonomy] terminology'.[192]

In summary, the author defines 'Automatic Systems', as systems which use pre-programmed instructions, however complex – these may be aided by Artificial Intelligence (AI) software. 'Autonomous Systems' are defined as systems that make decisions which are not based on specific directions from pre-programmed instructions, but more random decisions, based on their own interpretation of influences. This thesis uses the term 'autonomous', acknowledging that 'a high level of automation' is more accurate. The author argues that a high level of automation is actually how UCAS would be utilised. It is probable that UCAS will only act 'autonomously', when communications links are lost, and then, only in the sense that there is no human input into its decision-making, but as the decision making is based on pre-programmed instructions, the UCAS will still be in automation mode. This is an important distinction, as it should help both military and political decision makers understand the legal boundaries within which new weapon

[191] For a discussion on the viability of computer algorithms being able to perform better than humans in air combat, see Trsek, *op. cit.,* pp.13-14.

[192] See Tim Robinson, 'Unlocking the Skies', *Aerospace International*, January 2013, p.19.

systems are required to operate, according to the LOAC.[193] Whatever interpretation is used, automatic/autonomous systems are already in the inventory of most militaries. Cruise missiles, anti-radiation missiles, and AAM, are just some examples of weapons systems that once launched, use on- or off-board systems to continue to seek their target, independent of the launching platform. The US AEGIS Surface-to-Air Missile (SAM) sea-based system, and the Patriot SAM land-based system have been in service since the 1970/80s.[194] Both of these systems are intended to be operated automatically, in an environment that requires engagement decisions to be made more quickly than those by a human.[195]

The One-Seat versus Two-Seat Debate

A USAF Advanced Staff College paper views that, 'Airmen provide the flexibility and adaptability that is synonymous with airpower. UAVs will play a large role in our future but airmen will be required to ensure that UAVs are employed correctly and manned aircraft will be vital for dealing with the uncertainties of war'.[196] Previous arguments have questioned the requirement for one-seat versus two-seat. This question has divided air forces, on both sides of the Atlantic.[197] This section examines some of the issues that have challenged the development of single- and two-seat fighters, and whether we are now on the cusp of any aircrew being required at all.

Since the beginning of manned flight, pilots have been regarded as pivotal in the flying and operating of powered aircraft. The Wright brothers, initially bike makers, were the pioneers of powered flight. Other innovators added to the surge in aviation progress, with subsequent developments leading to aircraft capable of the full gamut of civil and military tasks, including transport, AAR, reconnaissance, bombing and air-to-air combat. Over time, other aircrew skills were required to help facilitate the ever-increasing complex requirements that flying, *per se*, required, particularly in military scenarios. These have included navigators, bomb aimers, observers, air engineers, air signallers, air electronic

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[193] This is discussed in Chapter 3.

[194] For a description of Patriot, see James O'Halloran and Christopher Foss (eds), *Jane's Land-Based Air Defence*, Twenty-fourth Edition, Coulsdon: IHS Jane's, 2011, pp.446-449. For a description of AEGIS, see Commander Malcolm Fuller RN (ed), *Jane's Naval Weapon Systems*, Coulsdon: IHS Jane's, 2011, pp.179-186.

[195] In its 2011 *Unmanned Systems Integrated Roadmap*, the US DoD uses four levels of autonomy, with a human making all the decisions at level one, and with no human interaction, unless for an emergency, at level four – see, *Unmanned Systems Integrated Roadmap FY 2011-2036*, p.46.

[196] See Major Robert C. Nolan II USAF, *The Pilotless Air Force? A Look at Replacing Human Operators with Advanced Technology*, Maxwell Air Force Base, AL: USAF Air University, 1997, p.36.

[197] See Lon O. Nordeen, *Air Warfare in the Missile Age*, Second Edition, Washington, DC: Smithsonian Books, 2002, pp.31-32.

operators, radio operators, air gunners, and latterly, WSO. Some of these airborne professions are now redundant, at least in those air forces equipped with modern aircraft and systems. The closure of the RAF's Air Navigation School in 2011 heralded a new era, where no new *ab Initio* WSO will be trained.[198] This was unthinkable even five years previously. Indeed, when the RAF's Tornado GR-4 goes out of service, the RAF will have no role for fast-jet qualified WSO. There are reasons for this – the main one being that, with the advent of the single-seat Typhoon, and the probable introduction of F-35 JSF, there is no perceived requirement for fast-jet WSO.

As technology has developed, the role of the navigator, and other associated airborne professions, has become less crucial. The change of professional status from navigator to WSO was an attempt to capture the many functions for which a navigator was responsible, with navigation being just one part.[199] Now defunct, the role of an AD navigator, for example, was always more of a battle manager, manipulating the air-to-air radar, the Link-16 based Joint Tactical Information Distribution System (JTIDS) – a TDL system, and other avionic systems, while directing the pilot of his aircraft, and other aircraft and crews in his formation, to a position where engagement of adversary aircraft could take place, hopefully with some advantage.[200] This was, more often than not, much harder to achieve than one would suppose. First, the adversary had to be detected, which could be challenging, especially when airborne sensors, such as radar, were not capable of detecting aircraft in a heavy clutter environment, created by ground returns and electronic warfare (EW) techniques. If an adversary was attempting to achieve the same aim, while utilising EA techniques, such as Digital Radio Frequency Memory (DRFM) jammers, against detection systems to confuse the air picture, engagements could be prolonged affairs, not always resulting in mission success.[201] In training scenarios, this produced battered egos at best; in real-world operations, it could have catastrophic consequences at worst.

Some advocates of the single-seat fighter use cockpit confusion as a reason against two-seat operations; it is also advocated that it does not take two men to handle the workload.

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[198] Royal Institute of Navigation, 'Farewell Navigator', (2011). http://www.rin.org.uk/news.aspx?ID=65&SectionID=23&ItemID=1323, (accessed 18 July 2012).

[199] See Lt Col Larry D. Magnuson USAF, *The Future of the Air Force Navigator,* Maxwell Air Force Base, AL: USAF Air University, 1989, Chap III, pp. 4-5. Magnuson explores the future requirements for WSO/navigators in the USAF, recognising the crucial role that navigators have in operating the weapon systems and creating situational awareness.

[200] See Wg Cdr Justin Reuter RAF, 'Joint Tactical Information Distribution System', in *25 Years of Air Defence: The Tornado F3*, Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.16-18. Reuter describes how the navigator in the Tornado F3 used JTIDS and other weapon systems.

[201] Flt Lt David Bennett RAF, 'Weapon Systems Officer', in *25 Years of Air Defence: Tornado F3*, Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.97-98. DRFM jammers are capable of emulating the coded waveform of radars, creating false information, potentially mitigating their use – see Curtis Schleher, *Electronic Warfare in the Information Age*, Boston: Artech House, 1999, pp.293-294.

The cockpit confusion objection to a two-seat fighter rests on concern that the need to take votes between cockpits delays the decision-making process. Craig Penrice, a former RAF test pilot for the Eurofighter Typhoon, with experience on the Lightning and F-15, certainly believes so, opining that, 'A modern, reliable defensive aids suite can easily do the job of the rear seat occupant during a dogfight'.[202] This can be true, if two weak, or two dominant, aircrew are crewed together. However, good crew-cooperation training, latterly referred to as crew resource management (CRM) by the RAF, has allowed the full benefits of two-crew operations to be realised.[203] Penrice does not mention CRM, perhaps because he has no operational experience in two-seat aircraft; he absolutely advocates, however, the virtues of the single-seat fighter, stating: '….I believe wholeheartedly that the single seat fighter is the only really viable way ahead for the future on the grounds of cost and operational effectiveness. Technical advances in the fields of sensor fusion allow a single pilot to have better situational awareness'.[204] Another pro-single-seat argument is that, although there are many tasks, they do not all come at once; therefore, a fighter pilot should be able to do them. However, while it is possible for one man to perform most tasks in a benign counter-air environment, it is an entirely different matter in poor weather, at night, when one's own systems are being jammed by EA.[205]

Improvements in radar and other sensor technology, aligned with increases in computer processing power, have meant more automation can be incorporated into weapon systems, particularly radars. This has allowed the better-designed fighters to dispense with the navigator/WSO. There have been concerns and problems along this developmental path, however. Nonetheless, fighters such as the F-22 Raptor, F-15 Eagle, F-16 Falcon, F-18 Hornet, Typhoon and Rafale, and the Russian Su-27 Flanker and MiG-29 Fulcrum, are all predominantly single-seat. Where there are two-seat versions of these aircraft, they are designed for use in mainly in the air-to-surface role, concentrating on the EA and SEAD tasks, against sophisticated IADS.[206] These missions have traditionally necessitated a

[202] Craig Penrice, 'Single Seat Fighter - the Way Ahead for the 21st Century', *Air and Space Europe* 2, no. 1, 2000, p.10.

[203] For a discussion on safety within military aviation, and the role that CRM can play, see Joseph L. Soeters and Peter C. Boer, 'Culture and Flight Safety in Military Avaition', *The International Journal of Aviation Psychology* 10, no. 2, 2000, pp.111-133.

[204] Penrice, *op. cit.,* p.14.

[205] There are some who disagree with the single-seat argument; for example, see generally, Major Joseph A. Papay USMC, 'Single-Seat Fighters: A Question of Survivability', (1989), http://www.globalsecurity.org/military/library/report/1989/PJA.htm, (accessed 19 April 2010). Papay argues against the trend for single-seat fighters, such as the F-18A, advocating two-seat versions as being more effective and survivable in contest battlespace. There was controversy over the two-seat F-4 Phantom during the Vietnam war, but there is little doubt that WSO helped win 'dogfights' - see Nordeen, *op. cit*., pp.31-32.

[206] For example, for background on the F-18G 'Growler', a two-seat version of the F-18, procured as a dedicated EW version, see Jackson, *op. cit.,* pp.653-654.

heavier workload on aircrew, which, until quite recently, has meant two-seat fast-jets have been required to achieve the task. On the other hand, the single-seat F-15C has proven to be an immensely capable air superiority fighter. Flown by, amongst others, the US and Israel, it has achieved a kill ratio of 105.5:0 in conflicts in the Middle East.[207] The F-22 Raptor is acknowledged as the preeminent fighter flying today and the only fifth-generation fighter operational.[208] The F-35 JSF is publicised as being capable of achieving all combat air power tasks; both of these aircraft are flown and operated by a single pilot.[209] Whether operated by a single pilot, or more aircrew, recent conflicts have seen the strategic decision-making during sorties having to be made by the aircrew, due to lack of communications with their C2.[210] The US Navy acknowledges the potential lack of C2, emphasising that future warfare:

> …could lead to a highly contested or even denied C2 environment where forces face a near total loss of their commercial and military-specific networking capabilities due to adversary action. Forces will be challenged to provide even one communication path for most information requirements. *Threats to the Navy's capabilities in this environment potentially involve a total loss of existing SATCOM and RF links, as well as a loss of GPS position navigation signals.*[211]

This is an important consideration; if unmanned air systems are to be utilised, mission critical decisions will need to be made autonomously, at times. If unable to do so, whether for technical reasons, or a lack of willingness to by commanders, the roles of UCAS will be severely curtailed.

Along with the trend towards single-seat aircraft operations, doctrine and tactics have evolved to take advantage of the transformation evolution that technological advances have allowed manned flight to utilise. What advances in flight does the future hold? With the demise of non-pilot aircrew, will advances in aviation systems mean there will be fewer requirements for pilots? The evolution of flying continues. Other than the actual act of flying an aircraft, historically, navigation has been deemed critical to mission success. For much of the history of flight accurate navigation has proven somewhat problematic, especially until the advent of inertial navigation systems, and, significantly, satellite-based navigation systems. Is technology just following a natural trend that means computers and

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[207] Steve Davies, *F-15C Eagles in Combat*, Oxford: Osprey Publishing Ltd, 2005, p.6.

[208] Jackson, *op. cit.,* pp.788-792.

[209] There is debate whether a two-seat variant of the JSF is required to conduct the more demanding tasks; see generally, Captain W. Suarez USMC, *JSF: The Need for a Two-Seat Variant,* Quantico, VA: Marine Corps University, 2008.

[210] For example, see Sqn Ldr Harvey Smyth RAF, 'A Harrier Mission Commander', in *Air Power: The Agile Air Force,* Neville Parton (ed), Shrivenham: Director of Defence Studies (RAF), 2007, pp.30-31.

[211] US Navy Information Dominance Corps, 'U.S. Navy Information Dominance Roadmap 2013-2028', http://www.public.navy.mil/fcc-c10f/Strategies/Information_Dominance_Roadmap_March_2013.pdf, (accessed 9 May 2013), p.8.

associated avionic systems will do the required task more efficiently? Are we now coming full circle, where navigation accuracy and the precision of weapon delivery is by far the predominant requirement for combat air power? Historically, the science, and some would say art, of navigation has taken precedence over many other aspects of warfare. Mastery of the sea required accurate navigation. The establishment of the Royal Observatory at Greenwich, and the fevered race to produce a timepiece allowing longitude to be calculated accurately enough to withstand the rigours of sea voyage, were fundamental to the success that Britain enjoyed as the primary sea power through the 18th and 19th centuries.[212] John Harrison's H1 timepiece, developed in the 1730s, allowing for accurate calculation of longitude, can be described as revolutionary.[213]

The Gulf Wars of 1991 and 2003, and COIN operations in Afghanistan and post-war Iraq, have demonstrated the vital role that precision weapon delivery plays in modern warfare. Russia and China have taken note of these advances in weaponry, and have been making steady advances in their development of comparable systems.[214] The primacy of navigation, and all that the mastery of it brings, is now, arguably, firmly established as the priority of any nation that wishes to have, and use effectively, a military force. The fact that pilots have historically been required to fly aircraft that facilitate achieving the requisite military task should not be a driver for future doctrine, tactics, or procurement. Technology now allows greater time, effort, and resources to be focused on systems that will not require a human interface in an aircraft. With the demise of the two-seat fighter and the development of UCAS, capable of undertaking ISTAR and SEAD roles, considering their use in counter-air tasks seems a reasonable step.

Potential Cost Benefits

Aircrew in high performance aircraft, capable of sustained high 'Gravity' (G) manoeuvring, can suffer marked physical effects. A UK study concluded that: 'Good evidence is available to show that aircrew of high performance aircraft will experience degeneration of the cervical spine during their career which is greater than that observed in the normal population'.[215] In 2010, the F-22 Raptor Force was grounded for a number of months,

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[212] See generally, Dava Sobel, *Longitude*, London: Fourth Estate Limited, 1995.

[213] Mark Largent, *Exploration and Science: Social Impact and Interaction*, Santa Babara, CA: ABC-CLIO, Inc., 2007, p.33.

[214] While air power is viewed as important in China's military modernisation, it was not until the 1991 Gulf War that there was any real appreciation of the importance of complete control of the air. In 1991, the Military Commission issued instructions for the PLA and all military academies to study the Gulf War - see Kenneth W. Allen, Glenn Krumel, and Johnathan D. Pollack, *China's Air Force Enters the 21st Century*, Santa Monica, CA: RAND Corporation, 1995, pp.31-33.

[215] Dr C.J. Edge and Dr V.M.Lee, *The Long-Term Health Effects of Flying High Performance Aircraft,* Farnborough: UK Ministry of Defence, 1999, p.19.

following the loss of an F-22, suspected to be caused by the aircraft's oxygen system malfunctioning and incapacitating the pilot. The F-22, like the F/A-18C/D, uses an on-board oxygen-generation system. These types of systems are required on aircraft to allow persistence.[216] While rectifiable, it illustrates the problems of having a human in the cockpit. Although the preservation of aircrew is undoubtedly important, it is questionable whether this will be paramount in any decision on UCAS development. The capability to operate longer than manned aircraft, and maintain persistence, are attributes that make UCAS every attractive. It is these attributes, and the economics and effectiveness of a system, including the cost of training aircrew and associated through-life costs (TLC), which are likely to affect decisions on procurement and capability. UCAS may well offer a significant TLC advantage over a manned system. Notwithstanding that manpower will still be required to operate an autonomous system, taking aircrew out of the equation could mean substantial savings. The cost of training a RAF Typhoon pilot to a point where he/she can start training on an operational squadron, for example, is £4 million, as of 2008.[217] Further training to actually become, and remain, capable of conducting operational tasks would be considerably more, perhaps as much as £9 million. This is based on the capitation cost (the calculation used for overall cost) of the RAF Typhoon being £92,000 per hour, with it taking approximately 60 hours further training on a squadron before a Typhoon pilot becomes fully operational.[218] Once operational, a Typhoon pilot currently requires 180 flying hours a year in order to conduct training to remain operational.[219] The operating costs of a UCAS would be significantly less, essentially because the UCAV remains on the ground, containerised, unless or until it is actually required for operations, or maintenance procedures.[220]

The cost of personnel normally forms the largest part of a country's military budget. For example, the actual cost of employing a relatively junior RAF officer, a flight lieutenant, is calculated using their annual salary, plus other associated costs. In 2011, an RAF flight

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[216] Bill Sweetman, 'Stealthy Danger: Hypoxia Incidents Troubling Hornets May Be Related to F-22 Crashes', *Aviation Week & Space Technology*, 18/25 July 2011, p.35.

[217] Obtained by the author through the UK Ministry of Defence, *Freedom of Information Act Respone: Ref - 15-02-2011-093156-009*9, 8 March 2012.

[218] Obtained by the author through the UK Ministry of Defence, *Freedom of Information Act Response: Ref: 14-02-2012-155233-007,* 12 March 2012.

[219] The NATO minimum flying hour requirement for aircrew to remain combat ready has for decades 15 hours per month - see John F. Schank and others, *Finding the Right Balance: Simulator and Live Training for Navy Units,* Santa Monica, CA: RAND Corporation, 2002, appendix D, p.133. This may change.

[220] Yenne, *op. cit*., p.109.

lieutenant pilot was paid on average £50,000, including flying pay.[221] The actual capitation cost includes annual salary, plus pension contributions (Superannuation Contribution Adjusted for Past Experience (SCAPE)) – for officers this is 42.8% for FY 2011/12, plus Earnings Related National Insurance Contributions (ERNIC) at 7.7%, plus housing, uniforms, training and other associated costs at 25%.[222] This brings the average annual capitation cost for a junior officer pilot to £87,800. The range of personnel costs will vary, according to rank; however, it can be broadly seen that by reducing manpower, costs can be significantly reduced.

A substantial cost saving in training and personnel can be gained by the use of simulation. Advances in this area are creating opportunities for improvement in training that were not previously thought possible. Most of the training and currency requirements could be achieved through distributed mission training (DMT) systems. Although the UK uses a number of these types of training systems, it is the USAF that has been at the forefront of the development of DMT, with its Live, Virtual and Constructive (LVC) Integrating Architecture (IA) (LVC-IA) Plan. USAF training specialists believe that the increased use of simulators and the ability to connect simulators and/or aircraft at dispersed locations, and new applications of LVC are essential allowing fifth-generation pilots are able to acquire the required skills, enabling training risks to be minimised.[223] LVC simulations allow aircrew and other personnel to conduct training to an extremely high- level of fidelity, and at significant cost savings. These systems may actually allow for better training - by offering the scenario that everything always works – aircraft and weapon systems, and C2 all work, and the weather is suitable - but, if required, effectiveness of individual systems and weapons could be degraded, to simulate austere operating conditions. This is preferable to the haphazard way in which most live flying training is currently conducted, where the vagaries of system serviceability and the whims of the weather, significantly impact on the value of training – at great wasted cost, and, ultimately, operational effectiveness.[224] There is a balance to be maintained, of course; however, technology advances should allow for the utilisation of these systems to greatly enhance the effectiveness of all air operations, including the use of UCAS, with associated cost savings.

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[221] This figure is based on an RAF flight lieutenant earning a basic £37,915 to £45,090, in addition to flying pay of £4800 to £14,200 per year. See 'UK Armed Forces Pay Rates: April 2011 - April 2012', HM Forces.co.uk, http://www.hmforces.co.uk/benefits/articles/8141-uk-armed-forces-pay-rates-april-2011---april-2012, (accessed 5 January 2012).

[222] Email correspondence between author and Sqn Ldr Keith Perry, Personnel Policy – Strategy SO2, RAF Air Command, 11 May 2010.

[223] John A. Ausink and others, *Investment Strategies for Improving Fifth-Generation Fighter Training*, Santa Monica, CA: RAND Corporation, 2011, p. xi.

[224] Royal Aeronautical Society, 'The Impact of Flight Simulation in Aerospace', *Specialist Paper*, www.raes-fsg.org.uk/download.php?mid=4, (accessed 31 January 2012), pp.2-3.

Leadership Challenges

Will future leaders of the military flying cadre have the necessary qualities to lead if they have never flown a military aircraft, let alone flown in combat? Indeed, would it be necessary for any of the operators of a UCAS to be combat experienced aircrew? The once pilot centric command hierarchy in the RAF is changing. The 2011 RAF Commander-in-Chief of Air Command, the second most senior officer in the RAF, was a navigator. The commander of the new UK Joint Forces Command, announced in 2011, was also a navigator. The 2nd edition of UK MOD's *AP3000: Air Power Doctrine* emphasises the importance of leadership, stating, 'Leadership can take many forms and styles both in the air and on the ground, but invariably includes professional mastery and moral courage'.[225] Although not emphasised in current publications, this is still pertinent. ACM Sir Stephen Dalton, believes that air power's significance is being diluted by a lack of understanding. Addressing a conference at the IISS in 2010, ACM Dalton stated:

> I would contend that air power is, and must be, our comparative advantage over potential opponents in future conflict. So success depends on our ability to exploit this critical advantage, through mastery of its capabilities by people who have the knowledge, professional expertise and competence to apply that advantage. Such mastery requires years of training, and our advantage must not be squandered by non-experts who do not really understand the third dimension – or relative and space advantage – that mastery of the air can deliver.[226]

ACM Dalton's views are relevant and hard-hitting; they get to the crux of the general malaise in the understanding of the attributes of air power, and should be a reminder to military leaders in all the disciplines and academics alike, that it is imperative to understand the dynamics of air power. The relevant skills are not easily gained, or maintained. This is axiomatic for sea and land power. ACM Dalton has also stated that those who fly UAS '….will be cut from the same cloth as their comrades in the air'.[227] Notwithstanding the prescience of Dalton's comments, would it be possible to have a Chief of the General Staff, who has not led soldiers in the field, or a Chief of the Naval Staff who has not captained a ship, or a Chief of the Air Staff who has no military flying experience?[228] Not least, a lack of emotional connectivity with the battlespace will require particular attention by military leaders. These are valid issues. However, they should not detract from frank analysis

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225 *AP 3000: Air Power Doctrine*, 2nd Edition, Norwich: Her Majestry's Stationery Office, 1993, p.1.2.15.

226 ACM Sir Stephen Dalton RAF, 'Dominant Air Power in the Information Age', 15 February 2010, http://www.raf.mod.uk/rafcms/mediafiles/D63BE198_5056_A318_A8E65DC502527B6A.pdf, (accessed 12 September 2012).

227 James Kirkup, 'The New RAF Pilots Who Will Never Fly into Battle', *The Daily Telegraph*, 14 December 2012, p.13.

228 In April 2013, the first four RAF non-flying pilots, Reaper UAS pilots, were awarded their 'wings'. This has caused some debate, but nonetheless, is an indication of where some future leaders of the RAF may come from – see 'Pilots Reaping Their Rewards', *RAF News*, 12 April 2013, p.9.

regarding the utility of UCAS in future warfare.[229] The US, at least, has acknowledged there is a lack of 'UAS-expert leaders', and aims to identify future UAS-expert senior leaders, integrating them into their Air and Joint Staffs.[230]

The UCAS Debate

The debate over the future utility of UCAS is fierce, particularly within the US military hierarchy. General Norton Schwartz, the USAF Chief of Staff in 2011, apparently rejected the development of a completely unmanned long-range bomber. Schwartz, speaking to reporters, outlined the current state of US technology stating in his view, "'… at least for the next 25 years, maybe 50 years, there's going to be a mix of manned and unmanned [aircraft]. Beyond 50 years, anything's possible'".[231] He also stated, ''…that he isn't ready to contemplate a nuclear sortie on a remotely piloted aircraft'".[232] His reasoning for this is not clear, after all, Intercontinental Ballistic Missiles, armed with nuclear warheads have been part of the US arsenal for decades. These cannot be recalled.

In contrast, also speaking to reporters, US Marine General James Cartwright, the vice chairman of the Joint Chiefs of Staff in 2011, stated he believes unmanned bomber technology is ready for deployment. General Cartwright, who was the Pentagon's top-level review panel with authority to determine all of the military's major hardware requirements , said the US should buy an affordable bomber to replace its ageing fleet of conventional-only B-1s and nuclear-capable B-52s and B-2s.

> What I'm trying to understand is: What is it we're going to build it for? Is it the most exquisite, high-end, penetrating, go-anyplace anytime weapon system…or is it a truck that has today's state-of-the-art survivability attributes, can incorporate the next-generation attributes in a way that makes sense…[including] sensors and whatnot…and carry reasonable payloads?[233]

Cartwright further stated that he would, '"throw down the gauntlet by asking whether the bomber truly requires a human pilot, or if instead all of them could be remotely controlled….Nobody's shown me anything that requires a person in that airplane.

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[229] For a range of essays on leadership and its relationship with air power, see generally, Peter W. Gray and Sebastian Cox (eds), *Air Power Leadership: Theory and Practice,* London: The Stationery Office, 2002.

[230] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 – 2047,* p.59.

[231] Eddie Walsh, 'US Air Force Faces Reality', *The Diplomat Magazine*, 25 September 2011, http://the-diplomat.com/new-leaders-forum/2011/09/25/us-air-force-faces-reality/, (accessed 8 October 2011).

[232] *ibid.*

[233] Elaine M. Grossman, 'Top General Says US Needs Fresh Look at Deterrence, Nuclear Triad', *Government Executive*, 14 July 2011, http://www.govexec.com/dailyfed/0711/071411-Cartwright-nukes.htm, (accessed 19 November 2011).

Nobody"'.[234] Whoever is correct, some military aviation analysts believe it is probable that the US has had UCAS projects in development for a number of years, including a probable project run by Northrop Grumman; this programme is likely to be a demonstrator for the US requirement for the original Next Generation Long-Range Strike System (NGLRSS) programme, now referred to as the Long-Range Strike Platform (LRSP).[235]

Concept of Operations

While a CONOPS is required for a UCAS, regardless of whether the platforms are manned or not, the doctrine with which forces are employed should remain constant. Future military actions, and specifically air power, will still likely be based on the extant principles of war and, specifically, manoeuvrability. Describing the Manoeuvrist Approach, UK MOD Defence Doctrine states: 'Emphasis is placed on the defeat, disruption or neutralisation of an opponent through ingenuity, even guile, rather than necessarily, or exclusively, through the destruction of his capability or gaining territory for its own sake'.[236] This is essentially the employment of forces on the battlefield through movement combined with firepower to gain advantage over an opponent. The air power characteristics of reach, speed, and flexibility are particularly relevant to manoeuvre warfare. Frans Osinga believes that the Manoeuvrist Approach is '…pure Boyd…', referring to Boyd's OODA Loop concept (this is examined in Chapter 4).[237]

The US has a formidable and deserved reputation for carrier operations. Beginning in earnest in the build-up to war in the Pacific in World War II, the US navy was pivotal in the joint campaign against Japan. So important was the carrier, the US Army acknowledged that, 'The decisive combat element in the Central Pacific was the large aircraft carrier…'.[238] The US Army Air Force, on the other hand, although acknowledging the crucial role of aircraft carriers during WW II, sought to emphasise the role of land-based air power, viewing the Leyte Gulf operation as an exemplar:

> ….air operations had been successfully coordinated with the advance of ground and naval forces in the southwest Pacific…It had been repeatedly recognised…that carrier-based airpower could extend the reach of amphibious operations,…provided land-based airpower

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[234] *ibid.*

[235] See David A. Fulghum and Bill Sweetman, 'Future ISR: New Capabilities Collide with Shrinking Budgets', *Aviation Week & Space Technology*, 29 August 2011, p.47. See also, Singer, *Wired for War*, p.119.

[236] See UK Ministry of Defence, *Joint Doctrine Publication 0-01: British Defence Doctrine*, 4th ed, Shrivenham: Development, Concepts and Doctrine Centre, 2011, p.5.

[237] Osinga, *Science, Strategy and War*, p.3.

[238] Louis Morton, *U.S. Army in World War II: The War in the Pacific - Strategy and Command: The First Two Years*, Washington, DC: Office of the Chief of Military History, Department of the Army, 1962, p.589.

> was in a position to take over promptly the primary responsibility…the capacity to stay there and fight it out for whatever term might be necessary to maintain air superiority…[239]

Permanence is one of the weaknesses of air power. Nonetheless, US carrier operations were so effective in projecting power that they rendered battleships obsolete.[240] This ability to conduct long-range strike and counter-air missions since World War II, including from carriers, has given the US a decisive military capability.[241] Is this now the case? Dr Thomas Ehrhard and Robert Work in, *Range, Persistence, Stealth and Networking: The Case for a Carrier Based Unmanned Combat Air System,* view current US capabilities to operate at long range as deficient. They believe that both land- and sea-based US fighter assets lack the necessary range and persistence for air campaigns in non-permissive scenarios.[242] These aircraft are best suited for striking targets at a maximum of 450 nm from their operating bases/carriers. Anti-Ship Ballistic Missiles (ASBM) and cruise missile threats are likely to force US Carrier Strike Groups (CSG) to operate at least 1000 nm from adversary borders.[243] Why is this relevant? Mark Gunzinger from the US Centre for Strategic and Budgetary Assessments (CSBA) believes that a number of states, including those of China and Iran, are investing in A2/AD doctrine that, '…poses a direct and formidable challenge to the traditional forms of US conventional power-projection in all operating domains'.[244] Andrew Krepinevich, and others, define '[A2] strategies [as actions] to prevent US forces entry into a theater of operations…[AD] operations aim to prevent their freedom of action in the more narrow confines of the area under an enemy's direct control'.[245] The US DoD defines A2 as: 'Action intended to slow deployment of friendly forces into a theater or cause forces to operate from distances farther from the locus of

239 Wesley Frank Craven and James Lea Cate (eds), *The Army Air Forces in World War II - the Pacific: Matterhorn to Nagasaki - June 1944 to August 1945*, Chicago: The University of Chicago Press, 1950, pp.ix-x.

240 Andrew F. Krepinvech, 'The Pentagon's Wasting Assets: The Eroding Foundations of American Power', *Foreign Affairs* 88, no. 4, 2009, p.26.

241 For an excellent overview of how the US conducts carrier operations, see generally, Rear Admiral Paul Gilcrist USN (Retd), *Feet Wet: Reflections of a Carrier Pilot*, Atglen, PA: Schiffer Military History, 1997.

242 Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for a Carrier-Based Unmanned Combat Air System,* Washington, DC: Center for Strategic and Budgetary Assessment, 2008, http://www.csbaonline.org/wp-content/uploads/2011/02/2008.06.18-The-Case-for-Carrier-Based-Unmanned-Combat-Air-System.pdf, (accessed 23 May 2009), pp.7-8.

243 *Ibid.,* p.8.

244 Mark A. Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike,* Washington, DC: Center for Strategic and Budgetary Assessments, 2010, http://www.csbaonline.org/wp-content/uploads/2010/09/2010.09.14-Sustaining-Americas-Strategic-Advantage-in-Long-Range-Strike.pdf, (accessed 29 August 2010), p.x. See also, US Navy Information Dominance Corps, *op. cit*., p.3.

245 Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge,* Washington, DC: Center for Strategic and Budgetary Assessments 2003, http://www.csbaonline.org/4Publications/PubLibrary/R.20030520.Meeting_the_Anti-A/R.20030520.Meeting_the_Anti-A.pdf, (accessed 14 September 2009), p.ii.

conflict than they would otherwise prefer A2 affects movement to a theater'.[246] AD is defined as: 'Action intended to impede friendly operations within areas where an adversary cannot or will not prevent access. AD affects maneuver within a theater'.[247]

While the US military currently enjoys a huge advantage over the PRC, the geography of the Western Pacific nullifies some of this superiority.[248] According to Gunzinger, scenarios involving such A2/AD systems would require US short-range land- and sea-based combat aircraft to operate from much longer ranges, curtailing their ability to attack land targets deep in adversary territory, greatly reducing sortie generation rates. The development of advanced IADS would probably make most areas impassable to non-stealthy aircraft and cruise missiles.[249]

Concentration of force is a fundamental principle of war that is particularly well suited to air power. Experience has shown that air power concentrated in both time and space is more effective in achieving an objective than if it were dispersed over a wider area and longer time.[250] Moreover, a concentrated force will use support forces more efficiently, increasing overall capability and survivability. Whether operating from carriers or land-based, UCAS would conduct missions as part of a COMAO concept. A COMAO formation normally consists of counter-air, strike, AAR, ISTAR and other supporting assets. Benefits of operating in large formations include minimising attrition by optimising mutual support and saturating adversary IADS, generally by concentrating force.[251] However, due to UCAS extended range and persistence, other assets may be stretched to support. Fundamental to the future employment of UCAS, will be their utility within COMAO packages. Ultimately, it may be possible for a large COMAO formation of combat and support aircraft, combining manned aircraft and UCAS, or made up entirely of UCAS, to operate together or autonomously. This autonomy may permit a quicker and more accurate response, allowing not only a high probability of survival, but ultimately the desired strategic effect being achieved.

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[246] Air-Sea Battle Office, 'Air-Sea Battle: Service Collaboration to Address Anti-Access & Area-Denial Challenges', May 2013, http://navylive.dodlive.mil/files/2013/06/ASB-26-June-2013.pdf, (accessed 26 June 2013), p.2.

[247] *ibid.*

[248] For China's strategy on impeding access to the US in times of conflict, see Roger Cliff and others, *Entering the Dragon's Lair: Chinese Antiaccess Strategies and Their Implications for the United States*, Santa Monica, CA: RAND Corporation, 2007, pp.51-79.

[249] Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike*, p.x.

[250] *AP 3002 – Air and Space Warfare,* 2nd Edition, Chap 1, p.8. This maxim has been the *modus operandi* of the RAF, almost since its inception - see, for example, A. H. Narracott, *Air Power in War*, London: Frederick Muller Ltd, 1945, p.160.

[251] For a description of a COMAO package, see *AP 3002 – Air and Space Warfare,* Chap 4, pp.8-10.

Summary

Current US led operations in Afghanistan utilise the advantages that UAS bring over manned aircraft, such as persistence and operating costs. Other nations, including China and Iran, have seen the force multiplier attributes of these systems. The momentum of UAS development is increasing worldwide. The next stage is the development and use of them in highly contested airspace; this will require a fundamental change in approach in a number of disciplines, including procurement, planning, doctrine, and the tactics used. This will not be easy – a thorough and robust understanding of the international environment over the coming decades is necessary to inform the debate. The types of situations in which any military system needs to operate, dictates that system's requirement. The relationships between nations will dictate the resources allocated to nations' military infrastructures. Predicting future conflicts poses problems; however, tensions and conflicts will continue to be a part of international relations.[252] According to a report from the US National Intelligence Council, there is an economic shift in emphasis away from the Organisation for Economic Cooperation and Development countries, to Asia. When observing on China's economic advancements, the report states, '….This high economic growth has resulted in an unprecedented demand for natural resources…it is evident that change is inevitable and that many stress points are likely to emerge in the future global environment'.[253] Economic constraints and competition over natural resources will likely create focal points that result in nations making claims and counter-claims, flexing their economic and military apparatus in attempts to achieve objectives.

A2/AD networks being developed by China, Iran and other states will pose unacceptably high risks to land- and sea-based forces, compelling them to operate initially as far as 1000 nm or more from an adversary's coastline. Aircraft with a range that is at least two to three times that of the F/A-18E/F Super Hornet or F-35 JSF are required, if combat air is to contribute to future operations.[254] According to Gunzinger, '…[these] land- and sea-based aircraft penetrating dense, sophisticated IADS will require all-aspect, broadband low-observable characteristics'.[255] If NEC assets are compromised, combat air will be required to operate effectively independent of these networks. Ultimately, the combination of range,

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[252] For a view on the similarity between the geopolitical situation between Britain and Germany prior to WW I, and the present day between the US and China, see Henry Kissinger, *On China*, London: Penguin Books, 2011, pp.514-515.

[253] National Intelligence Council, 'Global Scenarios to 2025', Dr Mathew J. Burrows (ed), 2011. http://www.dni.gov/nic/PDF_2025/2025_Global_Scenarios_to_2025.pdf, (accessed 4 May 2011), p. 8.

[254] For a background on range and persistence requirements for carrier-borne combat aircraft, see Work and Ehrhard, *op. cit*., pp.20-26.

[255] Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike,* p.11.

persistence, stealth, EA and autonomy will likely be the prerequisite for effective strike operations over the coming decades. These strike missions will necessitate operating in highly contested airspace, where control of the air will be required. UCAS capable of conducting all parts of this task may offer a solution to the range and persistence challenge. However, the cost of advanced military system development and implementation, and the returns to any civilian manufacturer, may have a significant impact on the ability of the military/industrial complex to pursue the development of UCAS. A balance between the requirements of the state and industry will always be difficult, but must be taken into account.

Persistence is a key force multiplier of UCAS. However, for missions requiring engagement of an adversary, weapons expenditure may become a limiting factor. Development of Directed Energy Weapons (DEW) may alleviate this problem by permitting a range of targets to be engaged, either lethally, or non-lethally, allowing an engagement capability to persist for as long as a UCAV can remain airborne.[256] The question of whether UCAS will ever be allowed to operate totally autonomously is an emotive one. The LOAC, which is based on Customary International Humanitarian Law, as defined by the International Committee of the Red Cross, may mean that the authorities are not willing to take the risk of allowing decisions to be made by a 'machine', without reach-back to a command centre.[257] UCAS, or any other system, manned or unmanned, that cannot operate autonomously when required, will only be of use in certain scenarios. Large state conflicts, that could mean the survivability of one state over another, may require a response that is currently not part of most nations' doctrine. A radical approach to this issue is required, particularly, if potential adversaries are prepared to use similar systems fully autonomously.

UCAS have the potential to offer a revolutionary new set of options with enormous long-term payoffs to air power in terms of expanded mission tasks, tactical deterrence and, importantly, affordability. Although ROE constraints and moral and political necessities may initially militate against full autonomy, the development of AI and Human-Machine-Interface (HMI) technology may offer a level of integration which enables a greater degree of certainty when conducting Combat Identification (CID) and Collateral Damage Estimation (CDE), than that of a Human-in-the-Loop system (HITL). This would allow missions to be

[256] For a description of DEW, including High-Power Microwave (HPM) weapons, see Schleher, *op. cit*., Chap 8, pp.471-478.

[257] For the origins of Customary International Humanitarian Law, see Jean-Marie Henckaerts and Louise Doswald-Beck, *Customary International Humanitarian Law - Volume I: Rules*, Cambridge: Cambridge University Press, 2005, pp.xxv-xxvii. For an opinion on why a fully autonomous mode of operation may be necessary, for example, if the only alternative was for the system returning to base, without having accomplished the task, see Singer, *Wired for War*, p.127. Singer also points out that there are situations when there is no time for a human to react - see *ibid.*

planned and then executed using on-board decision making – with a Human-on-the-Loop (HOTL) monitoring the system and taking action only when necessary, and perhaps, totally autonomously. Precision has been the driving characteristic of air power in recent conflicts. Although this will remain extant, with the advent of improved IADS and modern SAM, low probability of detection may become crucial, with EA, persistence, payload and discrimination also vital to the utilisation of air power. Persistence is enabled by a number of technologies, such as significant advances in propulsion and aerodynamics. Autonomous in-flight refuelling, potentially with unmanned tankers, and advanced power sources would allow for increased endurance. UCAS would stay on task for as long as fuel permits, and then leave the hostile airspace to refuel and return. Separating aircrews from their platforms is also a factor in increasing range and endurance. However, although UCAV can deploy over great distances and with a reduced logistic chains, their operating tempo may stretch any manned airborne supporting systems. If the TLC of a UCAS means that these systems are High Value Airborne Assets (HVAA), it may mean manned HVAA are required to protect them, thereby mitigating any advantage that these systems offer. In order to operate effectively, UCAS will need to be able to control the air space they fly. It is important, therefore, that UCAS are capable of operating independently of other HVAA, with a high chance of survival. This premise is at the crux of this thesis.

Chapter 3: Unmanned Combat Air Systems: Technical, Legal and Ethical Challenges

UCAS Developments

The development of UCAS worldwide is consistent with the evolution of UAS as a whole. Countries, such as Iran, see UAS as offering a significant problem to US maritime forces in the Gulf, for example. Stuart Yeh, in *Comparative Strategy,* argues: 'A small force of UAVs could decimate entire divisions of soldiers…destroy all aircraft in a given threater, and put Nimitz-class carriers out of action'.[258] Already discussed, the US DOD's *Unmanned Aircraft Systems Roadmap: 2005 – 2030*, outlines a programme for the development of UAS/UCAS. This roadmap is not policy, but it does give guidance on what is possible, if procurement leans towards unmanned systems. The US Joint-UCAS programme is quoted in the roadmap, but was cancelled in 2007. The US Navy has now taken over the development of the US UCAS, with its UCLASS programme (detailed in Chapter 2). A number of other US companies are mirroring Northrop Grumman's UCAS programmes, although, not necessarily aligned with seaborne operations in mind. Boeing has been developing the X-45 Phantom Ray UCAS. General Dynamics are developing the Predator-C Avenger. This system is a jet powered, semi-stealthy UAS, which has the potential to be more survivable than current UAS.[259] Whether Avenger type UAS have a place in warfare is debateable, as it appears that it is not a UCAS, as defined in this thesis. It would seem that this program is on hold in any case.[260] Other systems have been trialled, such as the Lockheed Polecat, which crashed during trials in 2006, and has since been cancelled.[261] Pictures published by bloggers on the web in 2009 of a strange looking UAS, led the USAF to acknowledge that it was fielding a stealthy UAS, the RQ-170.[262] It is believed that the RQ-170 is being utilised in and from Afghanistan in the ISR role.[263] Whatever its role, it seems to be a precursor to the shape of future UCAS. In December 2011, an RQ-170

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258 Stuart S. Yeh, 'A Failure of Imagination: Unmanned Aerial Vehicles and Internatinal Security', *Comparative Strategy* 30, 2011, p.229. Yeh's arguments may seem farfetched to some, but they are gaining credibility within military circles – see generally, *ibid*, pp.229-241.

259 Daly, *op. cit*., pp.335-337.

260 Lt Col Lawrence Spinetta and M. L. Cummings, 'Unloved Aerial Vehicles: Gutting Its UAV Plan, Air Force Sets a Course for Irrelevance', *Armed Forces Journal*, November 2012, p.8.

261 Graham Warwick, 'Lockheed Confirms P-175 Polecat UAV Crash', *Flightglobal*, 20 march 2007, http://www.flightglobal.com/articles/2007/03/20/212700/lockheed-confirms-p-175-polecat-uav-crash.html, (accessed 26 April 2009).

262 Stephen Trimble, 'USAF Reveals RQ-170 Sentinel Is New Stealth UAV', *Flightglobal*, 7 December 2009, http://www.flightglobal.com/articles/2009/12/07/335875/usaf-reveals-rq-170-sentinel-is-new-stealth-uav.html, (accessed 11 June 2010).

263 Scott Shane and David E. Sanger, 'Drone Crash in Iran Reveals Secret U.S. Surveillance Effort, *The New York Times*, 7 December, 2011, http://www.nytimes.com/2011/12/08/world/middleeast/drone-crash-in-iran-reveals-secret-us-surveillance-bid.html, (accessed 7 December 2011).

flying over Iranian territory was obtained by Iran, with open sources indicate that it is virtually unscathed.[264] The US has acknowledged the loss of an RQ-170 while on a mission over Iranian territory. Speculative reports suggest that the RQ-170 may have suffered a cyber-attack against its command-and-control system, allowing Iranian forces to take control of it.[265] Iranian officials have claimed they jammed the GPS and guided it to a landing area. Although Western experts indicate this is plausible, US officials blamed the loss on a malfunction.[266] There is little doubt that Iran will attempt to reverse engineer the RQ-170. How damaging this may be to any technological advantage the US has in UAS/UCAS development is difficult to make comment on. However, in May 2013, photos of what appears like an RQ-170 taxiing at an airfield in China, appeared on a Chinese website.[267]

The *US UAS Roadmap 2005 – 2030* and *USAF UAS Flight Plan 2009 – 2047,* detailed earlier, give details of the possible timelines for the different systems and missions for which UAS/UCAS could be utilised. The USAF is analysing the requirement for a follow on to the MQ-9 Reaper UAS. Its vision is for a medium sized UAS, referred to as the MQ-M, to be operational by 2020; it will be required to have:

> .…an enhanced autonomy, modular, open architecture and networked system built around a common core airframe…[while] incorporat[ing] modular structural elements as well as payloads for optimal mission performance. The sensors will be interchangeable...[with an] open architecture interface for weapons allows air-to-ground and air-to-air weapons employment from current and future weapon inventories. As the MQ-M evolves over time an air refuelling configuration in the 2030 timeframe will allow the aircraft to serve as a small tanker, extending the missions of other aircraft.[268]

From approximately 2030 onwards, the *USAF UAS Fight Plan* foresees the MQ-Mc version capable of performing a number of roles including: autonomous swarm, aero-medical evacuation, personnel recovery, EW, SEAD, ISTAR, CAS, air interdiction, AAR as a tanker, missile defence, strategic attack, and counter-air missions.[269] These counter-air missions are defined within the *USAF UAS Flight Plan* as DCA missions. Larger UAS, nominated as MQ-L, will be capable of all of these roles, additionally, Battle Management Command and Control (BMC2), Joint Surveillance Target Attack Radar System, AWACS, air mobility and

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[264] *ibid.*

[265] David Majumdar, 'Iran's Captued RQ-170: How Bad Is the Damage?', *Air Force Times,* http://www.airforcetimes.com/news/2011/12/defense-iran-captured-rq-170-how-bad-120911/, (accessed 11 December 2011).

[266] Defense Systems Staff, 'Iran Claims It Hijacked RQ-170 by GPS Tampering', *DefenseSystems*, 16 December 2011, http://defensesystems.com/articles/2011/12/16/agg-iran-electronic-warfare-rq-170-uav.aspx, (accessed 18 February 2012).

[267] Sina.com, 'New Photo Shows That China Has Really Copied the U.S. RQ-170 Sential Stealth Drone', 2 June 2013, http://slide.mil.news.sina.com.cn/slide_8_34780_23923.html, (accessed 4 June 2013).

[268] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047,* p.38.

[269] *ibid.*

humanitarian assistance operations, but excluding counter-air.[270] In the Special System category, the roles of LO persistent and penetrating ISR and SEAD, hypersonic ISR, C2, lift, and strike are emphasised as specialised roles. These missions will demand high levels of autonomy, and the capability for ultra-long endurance or hypersonic flight. Significantly, due to the sensitive nature of these types of UAS/UCAS programmes, they will be developed in the classified domain.[271]

In 2006, the US DoD's Quadrennial Defense Review concluded that the USAF should accelerate the fielding of its NGLRSS from 2037 to 2018.[272] It is envisaged that 80 to 100 of the aircraft are to be built.[273] Looking forward to 2025, for a replacement for the F/A-18E/F and F-22, Boeing are working on design concepts for a sixth-generation fighter; conceptually, its design will be stealthy, tailless, with the ability to super-cruise, and, significantly, will be optionally manned.[274] This has traction with some aviation experts, as it is far easier to make a stealthy air vehicle if it is unmanned, as there is no requirement to have a cockpit with very reflective surfaces – so attractive to radars.[275]

The UK has collaborated with the US on a UCAS programme (referred to as 'Project Churchill'), forming a partnership in establishing a CONOPS.[276] This project ceased in 2009, but has, nonetheless, proved extremely valuable in allowing fundamental research to be undertaken. As already mentioned, as part of the overarching DPOC study, BAE Systems has been awarded a contract by the UK MOD to build a UCAS, as a technology risk reduction demonstrator. A European consortium of six counties, led by Dassault Aviation, aims to have its own UCAS Project, *NEURON*.[277] All of these programmes are demonstrators; they are not necessarily intended to become operational systems. Their successes, or otherwise, will help inform future procurement decisions. Unlike the US, there are no UK, or European equivalents, of the *US UAS Roadmap 2005 – 2030* and

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270 *ibid.*

271 *ibid.,* pp.40-41.

272 Robert Haffa and Michael Isherwood, *The 2018 Bomber: The Case for Accelerating the Next Generation Long-Range Strike System,* Los Angelas, CA: Northrop Grumman Analysis Center, 2008, p.1.

273 Elaine M. Grossman, 'Pentagon Budget May Omit Funds for Promised ICBM Modernization Study', *NTI: Global Security Newswire*, 15 February 2011, http://gsn.nti.org/gsn/nw_20110215_9437.php, (accessed 16 February 2011).

274 Caitlin Harrington, 'Boeing Unveils Concepts for Sixth-Generation Fighter', *Jane's Defence Weekly*, 19 May 2010, p.5.

275 See Schleher, *op. cit.,* p.508.

276 UCAS Programme Manager Capt Rich Brasel USN, 'Navy Unmanned Combat Air System Demonstration: Presentation to Precision Strike Association', USN NAVAIR, Washington, DC: US Department of Defense, 2006, http://www.dtic.mil/ndia/2006psa_peo/deppe.pdf, (accessed 14 April 2009), slide 9.

277 Daly, *op. cit*., p.8.

USAF UAS Flight Plan 2009 – 2047. Making informed comment on these countries' UCAS ambitions is, therefore, difficult.

It is likely that the People's Liberation Army Air Force (PLAAF) is developing concepts for UCAS along the same lines as Western doctrine, with UCAV that can conduct AAR, and able to conduct long-range missions, including ISTAR, strike and SEAD.[278] Since first appearing at the 2006 Zhuhai air show as an advanced UCAS concept, *An Jian* (*Dark Sword)* has posed questions for Western analysts about its proposed role. Initially portrayed as being intended for air-to-air superiority roles, the design reflects the potential for a combination of concepts. Due to its size, and corresponding fuel capacity, a UCAV of this type could theoretically support air-to-air operations after reaching its target. According to Peter La-Franchi, a defence analyst from *Flightglobal:* '…Dark Sword hints at an operational concept that is part of developing ideas for the conduct of extremely long-range deployments, followed by highly dynamic operations'.[279] Although this objective is technologically challenging, it is consistent with the People's Liberation Army's (PLA) desired approach to be able to engage a future adversary at great distances. At the Zhuhai Air Show, a representative called the aircraft the, '…future of Chinese unmanned combat aviation…', emphasising its projected ability to evade enemy radar and to engage in air-to-air combat.[280]

The *Dark Sword* concept may well represent an attempt to field a counter-air UCAS.[281] However, it appears very conceptual. A counter-air UCAS would require far more than just a very fast, high-altitude capable and manoeuvrable airframe. It is the avionics, sensors and networking capabilities that are fundamental to this type of system. That said, China's showing of its J-20 and J-31 5th Generation stealth fighters in 2011 and 2012 respectively, demonstrates how quickly it can develop concepts.[282] It is likely that future UCAS developments are aligned with China's A2/AD doctrine, and that these systems will form

[278] See Ian M. Easton and L.C. Russell Hsiao, *The Chinese People's Liberation Army's Unmanned Aerial Vehicle Project: Organizational Capacities and Operational Capabilities',* Arlington, VA: Project 2049 Institute, 2013), http://project2049.net/documents/uav_easton_hsiao.pdf, (accessed 13 March 2013), p.12.

[279] Peter La-Franchi, China's Dark Sword Unmanned Combat Air Vehicle Programme Raises Questions', *Flightglobal,* (17 October 2007). http://www.flightglobal.com/articles/2007/10/17/218683/chinas-dark-sword-unmanned-combat-air-vehicle-programme-raises.html, (accessed 25 November 2010).

[280] Kospoth, *op. cit*. See also, Bradley Pitt and Maxim Pyadushkin, 'Unmanned in the East', *Aviation Week & Space Technology*, 9 July 2012, p.102.

[281] Douglas Barrie and Alexey Komarov, 'Fighter Order Rekindles Russian Air Force', *Aviation Week*, 26 August 2009, http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=defense&id=news/RUSSAF082609.xml, (accessed 2 March 2010).

[282] Abdullah, *The Military Balance: 2013*, p.254.

part of the matrix of sensors and weapon systems China aspires to in building a viable deterrent force, and one also capable of enforcing its aims, if required.[283]

The unveiling of a full-scale mock-up of a Russian UCAV at the 2007 MAKS Air Show, highlighted Russia's desire to venture into UCAS development. The *Skat* UCAV was seen again at the 2009 MAKS Air Show. As recently as June 2013, RAC MiG have announced that a research and development contract has been signed with the Russian Defence Ministry to build a prototype.[284] Mayor General Oleg Barmin, chief of procurement for the Russian air force in 2011, has suggested that the UCAV could carry the same weapons as the PAK-FA 5th Generation fighter.[285] MiG and Sukhoi are also working together on UCAS developments. Sukhoi General Designer, Mikhail Pogosyan, has commented that the development of a UCAV could be the first common effort between the two fighter manufacturers.[286] How these would fit in with manned systems is difficult to judge; however, UCAS would probably need to be used in the same way as Western systems. Russian support of UAS/UCAS, however, is not universal. Nikolay Chistyakov, chief UAS designer at Novik 21st Century Science and Production Design Centre, has stated: 'In my view, the role of the UAV in contemporary conflicts has been considerably overrated…the current vogue for strike-capable UAVs is altogether a total absurdity…Far simpler to bring up a D-30 howitzer battalion and raze to the ground the area being targeted for strike…'.[287] Whether this is indicative of policy within Russia's military hierarchy, or if Chistyakov is just displaying a level of naivety and lack of understanding of the basics of air power that borders on ludicrous, is difficult to judge. Perhaps Russia does not intend to enter into strategic UAS/UCAS development to any great extent. It is possible that Russia's desire to enhance its own UAS industrial base is as much an attempt to enter the World UAS/UCAS market, than gaining military capabilities.[288] See Appendix I for examples of current International UCAS programmes.

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[283] See Mark Stokes, *China's Evolving Conventional Strategic Strike Capability: The Anti-Ship Ballistic Missile Challenge to U.S. Maritime Operations in the Western Pacific and Beyond*, Washington, DC: Project 2049 Institute, 14 September 2009, http://project2049.net/documents/chinese_anti_ship_ballistic_missile_asbm.pdf, (accessed 23 August 2010), pp.14 and 18. For analysis of Chinese UAS programmes, see James Bussert, 'Chinese Navy Employs UAV Assets', *Armed Forces Communications and Electronics Association*, 2012, http://www.afcea.org/content/?q=node/2918, (accessed 3 August 2012).

[284] Zach Rosenberg, 'RAC MiG to Design SKAT-Based Unmanned Combat Air Vehicle', 3 June 2013, http://www.flightglobal.com/news/articles/rac-mig-to-design-skat-based-unmanned-combat-air-vehicle-386609/, (accessed 4 June 2013).

[285] For PAK-FA development progress and potential weapons capabilities, which would likely include the latest Russian AAM - see Jackson, *op. cit.,* pp.513-515.

[286] Barrie and Komarov, *op. cit*.

[287] Victor Savenok, 'Was the Beast of Kandahar Brought Down by Our Avotobaza?', *Moscow Svobodnaya Pressa*, 12 December 2011, p.23.

[288] Harrington Lee, 'Armed and Dangerous', p.38.

UCAS Technological Challenges

The necessary components of a counter-air campaign are examined in Chapter 4. Most, if not all, of these components will be necessary for the successful utility of future UCAS. The future challenges that these systems will face requires reviewing. The weapon systems, sensors, overall airframe, and engine design that UCAS require, are fundamental to their successful development, and ultimately, the doctrine by which they will be employed. Whether the air vehicle itself requires being as manoeuvrable as the F-22 Raptor, for example, in the close-combat arena, is an important consideration. To this end, part of the author's research asks the question: 'How often, since the Vietnam War, has it been necessary to use a fighter's AAG as a means to achieve a kill?[289] As previously discussed, from interviews conducted with a number of counter-air aircrew, the available evidence suggests that an AAG is not required, although it may be another matter for low-intensity operations in an air-to-surface role.[290] This does not mean that a visual manoeuvring capability for visual combat will not be necessary. To what extent, however, will depend on how well NEC is integrated, aligned with the employment of HOBS AAM.

Jason Bowman, from the US Air Force Research Laboratory (AFRL), believes that the distinction between 'manned' and 'unmanned' systems will erode; the person is no longer limited by the aircraft, and it is not pilots, but mission managers that will be required. Significantly, Bowman considers that UAS will need to become more survivable to allow operating in contested and denied airspace. In his view, UAS will require speed, manoeuvrability, EW capability and visual, acoustic and IR stealth in contested airspace; in addition, in denied airspace. UAS will also require airframe shaping, materials and aperture technology.[291] The importance of TDL and communications, particularly the vulnerability of satellites was emphasised. Ultimately, Bowman believes, there is a significant potential in the utility of UAS to increase cost effectiveness, without going to the extremes of stealth and speed. Perhaps, most importantly, he believes the issue of autonomy is not new, sighting the example of the US Navy AEGIS SAM system and cruise missile, which the US has been comfortable with since the 1970s.[292] Philippe Koff, head of the European *NEURON* UCAS project, believes that there is a balance between LO and stealth, and that air-to-air missions need some thought, particularly for the 2030-40 epoch, and if used correctly, autonomy will make TDL and communication links less susceptible.[293] Both Bowman's and Koff's views are important; they indicate where European and US

[289] See analysis at Appendix B.

[290] See analysis in Chapter 1.

[291] Discussion with the author, 5 June 2010 – under KCL's Serendipity Rule.

[292] *ibid.*

[293] *ibid.*

UCAS doctrine may be heading. The views of the majority of responders to the questionnaire also align with this.

Advances in a broad range of technologies have begun to enable the integration of joint-forces, not previously possible. Perhaps the most significant is the expansion in computing technology. The principle of 'Moore's Law' has been proven correct, thus far. The *Unmanned Aircraft Systems Roadmap: 2005 – 2030* emphasises this, stating: '[that if the ultimate goal is to replace aircrew with a system of]…superior capacity, and responses gained from training and experience, then processors of human-like speed, memory, and situational adaptability are necessary'.[294] According to the *Roadmap,* human capabilities are generally agreed to equate to 100 million million-instructions-per-second in speed, and 100 million megabytes in memory; the cost of developing a system that could conduct most human thought processes is currently uncompetitive with that of a trained human. It is likely, though, that by 2030 the cost of a 100 million MIPS processor should approach $(US) 10,000.[295] Raymond Kurzweil, a prominent computer technologist, believes that the inevitable rate of continuing growth in processing power means there will be a point in the future where the rules of ordinary physics do not apply, sometimes referred to as *singularity*. Kurzweil's analysis of the exponential growth of processing power agrees with Moore's Law. He believes that the human brain will be successfully reversed engineered by the mid-2020s, and by 2030 computers will be capable of human-level intelligence. Kurzweil estimates, that by 2045, due to the vast increases in computing power and the reductions in cost, '…the quantity of artificial intelligence created will be about a billion times the sum of all human intelligence that exists today'.[296] Kurzweil's views are not universally accepted, but they are worth considering.

The limit of computer processing power has been predicted many times; however, Justin Rattner, Chief Technology Officer of Intel Corporation, believes this is not the case:

> In some sense - silicon gate CMOS [Complementary Metal-Oxide-Semiconductor] - Moore's law ended last year…One of the founding laws of accelerating returns ends. But there are a lot of smart people at Intel and they able to reinvent the cruise CMOS transistor using new materials. Intel is now looking beyond 2020 at photonics and quantum effects such as spin…The arc of Moore's Law brings singularity ever closer.[297]

[294] *Unmanned Aircraft Systems Roadmap: 2005 - 2030,* p.48.

[295] *ibid.*

[296] Lev Grossman, 'Sin.Gu.Lar.I.Ty *N:* The Moment When Technological Change Becomes So Rapid and Profound, it Represents a Rupture in the Fabric of Human History', *Time*, 21 February 2011, pp.23-24.

[297] Wendy M Glossman, 'Will Machines Outsmart Man?', *The Guardian*, 6 November 2008, p.1.

This is not an isolated view. Peter Cochrane, the former head of BT's research labs, believes that for machines to outsmart humans:

> ….depends on almost one factor alone - the number of networked sensors. Intelligence is more to do with sensory ability than memory and computing power….The internet overtook the capacity of a single human brain in 2006….I reckon we're looking at the 2020 timeframe for a significant machine intelligence to emerge….By 2030 it really should be game over.[298]

What does this mean for future UCAS development? It is assumed that UCAS will use AI technology such as 'Agent' software. There is no universal definition of AI; Andrew Ilachinski, from the Center for Naval Analyses, describes Artificial Life, as, '…using artificial components (such as computer programs) to capture the behavioural essence of living systems'.[299] Agent programs have evolved from other legacy AI software, such as Fuzzy Logic and Neural Networks; these are now maturing into a feasible technology, aligned with a viable HMI. Agents are normally defined as self-governing (autonomous), problem-solving computational units capable of effective operation in dynamic and open environments. They are often deployed in environments in which they interact, and sometimes cooperate with other agents (including both people and software) that have possibly conflicting aims. These situations are known as multi-agent systems. Essentially, Agent programs are autonomous entities capable of exercising choice over their actions and interactions, acting in order to achieve individual objectives.[300]

Current UCAS programmes indicate that their UCAV are not high performing airframes in the classic fighter sense. That is to say, they do not have a supersonic, very high level, capability. The X-47C UAS-D as an example, is capable of heights and speeds of 40,000 ft. and M0.85.[301] These are well below current counter-air aircraft traits, such as the F-22.[302] These aspects of air-to-air combat are normally fundamental to the success of BVR engagements, unless other aspects of the vehicle's design mitigate this advantage, for example, stealth technology, which may allow a platform to get close enough to an adversary, unseen, allowing first use of AAM, before the adversary's detection systems have allowed them to launch their own AAM**.** Already established, in its simplest form, the higher and faster a fighter aircraft can fly the further and faster its AAM will go, the larger

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[298] *ibid.*

[299] See Andrew Ilachinski, *Artificial War: Multiagent-Based Simulation of Combat*, New Jersey: World Scientific, 2004, p.25.

[300] For an excellent explanation of what Multi- and Intelligent-Agents are, see Michael Woolridge, *An Introduction to Multi-Agent Systems*, 2nd Edition, Chichester: John Wiley & Sons Ltd, 2009, pp.21-28.

[301] Daly, *op. cit.,* pp.374-376.

[302] The F-22, for example, can fly above 50,000 ft. and Mach 2.0+ - see *The Official Web Site of the U.S. Air Force*, 'F-22 Raptor Fact Sheet', 2012, http://www.af.mil/information/factsheets/factsheet.asp?fsID=199, (accessed 30 July 2012). See also, Jackson, *op. cit.,* p.513.

the distance between fighters at AAM impact.[303] This may enable the fighter to stay outside an adversary's AAM Missile Engagement Zone (MEZ), while allowing the aircrew time to plan and coordinate the appropriate tactics, and escape, if necessary.[304]

Future Weapon Systems and Autonomy Capabilities

Barry Watts, in *Six Decades of Guided Munitions and Battle Networks,* argues that a long-term problem for the US is, how long can it have superiority in guided munitions and Networked Centric Warfare (NCW) capabilities? China is currently focused on exploiting guided munitions and battle networks, primarily as an A2/AD. However, in the long-term, China may be the most likely state to field combat systems capable of opposing those of the US. US supremacy does not mean that rivalry in this area has ended.[305] This does not mean that weapon delivery technology will stagnate at the endpoint; other, more effective means of delivering objectives are likely to have their own revolution.

Unless AAM and SAM systems are developed that achieve an acceptable level of kill probability, then alternative means will be required. DEW could radically transform the conduct of future warfare. From the perspective of the current guided-munitions regime, DEW appears, on balance, to be a technology that could eventually produce radical and far-reaching changes in the conduct of war. DEW not only offers the possibility of achieving an extremely fast kill through vastly improve weapon systems, but, in an application such as the intercept of ballistic missiles, cruise missiles, AAM, and SAM, extend the maximum feasible range of aimed, line-of-sight weapons to several hundred nm.[306]

The USAF appears to be leading the field in AI and autonomy programmes. The *USAF UAS Flight Plan* envisages, '… a fully autonomous capability, swarming, and Hypersonic technology to put the enemy off balance by being able to almost instantaneously create effects throughout the battlespace'.[307] The aim is, to get inside an adversary's OODA Loop.[308] The leadership of the RAF also understands the implications of the revolution that

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303 Shaw, *op. cit.,* pp.51-52.

304 Forms of EA capability may reduce this advantage, but this kinematic principle is fundamental to all BVR air-to-air engagements. For the effects that EA can have, see Schleher, *op. cit*., pp.293-294.

305 Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*, Washington, DC: Center for Budgetary Assessments, 2007, http://www.csbaonline.org/publications/2007/03/six-decades-of-guided-munitions-and-battle-networks-progress-and-prospects/, (accessed 15 May 2009), p.290.

306 *ibid*., p.284.

307 *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047,* p.50.

308 John Boyd's OODA Loop concept is examined in Chapter 4. For an excellent biography of Boyd, see Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War*, New York: Back Bay Books, 2002.

weapons technology can bring to the effectiveness of future combat air structures. In 2011, the RAF's CAS, ACM Sir Stephen Dalton, remarked to reporters: '"…There's a lot more capability out there in terms of using microwaves, heat waves and lasers, and we need to further our understanding of them…,we might be able to use a [DEW] of some form or other from a non-combat platform…"'.[309]

Autonomy

Although responses to the author's questionnaire established that the vast majority (89%) of military professionals do not believe that UCAS should always need a human interface, it is not an unreasonable aspiration, although it may not always be possible, or indeed practical.[310] Communication bandwidth constraints may not allow for full-time two-way communications with C2, the UCAS GCS and the UCAV. Operating deep into adversary territory may militate against robust communications. Not least, decisions made by a HITL, or indeed, a HOTL, may not be quick enough to attain the desired aim. It is, therefore, crucial to at least investigate the effectiveness that autonomous UCAS operations may have in achieving the commander's intent. The USAF, in its *UAS Flight Plan 2009 – 2047*, believes that advances in computing speeds and capacity will change how technology affects the OODA Loop, ostensibly supporting the concept of a HOTL:

> Today the role of technology is changing from supporting to fully participating with humans in each step of the process. In 2047 [the USAF predicts] technology will be able to reduce the time to complete the OODA loop to micro or nanoseconds….Increasingly humans will no longer be "in the loop" but rather "on the loop" – monitoring the execution of certain decisions. Simultaneously, advances in AI will enable systems to make combat decisions and act within legal and policy constraints without necessarily requiring human input.[311]

If some degree of autonomy is authorised, the ability to retain and refine the level of autonomy the systems use will be fundamental to their effectiveness. This should be established by mission role and in some cases within the phase of the mission, just as is the current doctrine for manned systems. The USAF requires that: 'To achieve a "perceive and act" decision vector capability, UAS [UCAS] must achieve a level of trust approaching that of humans charged with executing missions'.[312] Although it is acknowledged that UCAS AI/autonomy should be based on human intent, the USAF envisages that humans will still be required to monitor the execution of operations and retain the ability to override

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[309] Mark Ayton, 'Driving the RAF Forward', *Air International*, April 2010, p.34. The US is at the forefront of airborne laser development. The Airborne Laser Laboratory, a specially designed Boeing 747, was equipped with a high-power laser to destroy theatre Ballistic Missiles. Trials were also conducted against air-to-air missiles - see Robert W. Duffner, *Airborne Laser: Bullets of Light,* New York: Plenum Press, 1997, pp.225-253 and 279-296. Development of airborne laser continues, with the latest US test firing in 2010 – see Hewson, *op. cit*., p.110.

[310] Singer, *Wired for War*, pp.123-124.

[311] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047,* p.41.

[312] *ibid.*

the system or change the level of autonomy during the mission, with a HOTL at all times. Whether this is possible in a communications link denied environment is crucial to whether UCAS could, or would be authorised to, operate totally autonomously, if this was the only mechanism by which the 'system' could achieve the commander's intent.

A metric by which autonomy levels are measured is required in order to understand what is necessary for successful operation. However, before any metric can be designed, an appreciation of the complexities which an unmanned system may encounter, and the tasks required of that system, is necessary. As technology advances, the autonomy on board these systems also advances. As autonomy cannot be evaluated quantitatively without sound and thorough technical basis, the development of autonomy levels for unmanned systems must take into account many factors such as task complexity, human interaction, and environmental challenges.[313]

A paper from the UK's Defence Evaluation and Research Agency (DERA), in 2000, describes a real-time adaptive automation and real-time task, interface and timeline management tool, designed to support pilot operations, while using computerised assistance. Referred to as Pilot Authorisation of Control of Tasks (PACT) Levels, 'The PACT system uses military terminology to distinguish realistic operational relationships for five aiding levels, with progressive pilot authority and computer autonomy supporting situation assessment, decision making and action'.[314] Six levels of control are offered: Level 0, has no computer autonomy, with the pilot having full authority and control; Level 1 introduces computer assistance to the pilot when requested; Level 2 uses the computer to offer advice, but the pilot needs to accept it; Level 3 uses computing to conduct tasks, with the pilot accepting or rejecting the recommendations; Level 4 – the computer conducts all tasks, unless revoked, and Level 5 is fully automatic, with monitoring only.[315]

Another example of giving metrics to different levels of autonomy is used by the US National Air and Space Administration (NASA). NASA uses the Function-specific Level of Autonomy and Automation Tool (FLOAAT). NASA has constructed this tool to aid its future Crew Exploration Vehicle, as this will be designed at higher levels of autonomy and automation than previous NASA vehicles. This is due to a number of reasons, including, significantly, communication delays, as well as computer enhancements, and the

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[313] Hui-Min Huang and others, *Specifiying Autonomy Levels for Unmanned Systems: Interim Report,* Gaithersburg: National Institute of Standards and Technology, 2003, p.43.

[314] Michael Bonner, Robert Taylor, and Keith Fletcher, 'Adaptive Automation and Decision Aiding in the Military Fast Jet Domain', *Technology*, 2000, p.157.

[315] *ibid.,* p.158.

emergence of highly reliable decision-making algorithms.[316] At the centre of this evolution in design are the questions, '"What is the *right* balance of ground versus on-board authority (autonomy)?" [and] "What is the *right* balance of human vs. computer authority (automation)?"' [317] The strength of FLOAAT is that it is a practical concept of separate levels of automation and autonomy, based on Boyd's OODA Loop of 'observe, orient, decide and act'.[318] These studies have not gone unnoticed in China; an article in a journal from Beihang University, proposes 9 levels of autonomous control for UAS, with level 9 being for fully autonomous control.[319] From the DERA PACT and NASA examples, it is relatively easy to transpose appropriate levels for use when referring to how a UCAS could be utilised. Keeping their five levels of autonomy, the following is the author's interpretation of autonomy levels for UCAS. Table 1 describes these definitions and levels of autonomy.

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[316] Ryan W. Proud and Jeremy J. Hart, *FLOAAT, a Tool for Determining Levels of Autonomy and Automation, Applied to Human-Rated Space Systems,* Arlington: American Institute of Aeronautics and Astronautics, 2005, p.1.

[317] *ibid.*

[318] NASA's FLOAAT giving levels of autonomy is at Appendix F.

[319] Chen Zongji, 'UAV Autonomous Control Levels and Systems', *ACTA Aeronautica Et Astronautica Sinica'* 32, no. 6, 2011, Table 2, p.1079.

Level	Observe	Orient	Decide	Act
5	On-board sensors operate autonomously. Data assessed by UCAS. No HOTL.	Data used by UCAS. No HOTL.	Decision made by UCAS. No HOTL	Task executed by UCAS. No HOTL.
4	On-board sensors operate autonomously. Data assessed by UCAS. HOTL monitoring.	Data used by UCAS. HOTL monitoring.	Decision made by UCAS. HOTL monitoring.	Task executed by UCAS. HOTL can stop the task, if required.
3	On-board sensors operate autonomously. HITL can allocate sensor types.	Data used by UCAS. HITL monitoring.	Decision made by UCAS. HITL can alter decision	HITL required to authorise execution of task, by accepting or rejecting.
2	On-board sensors operate autonomously. HITL can allocate sensor types.	Data used by HITL.	Decision made by HITL.	HITL authorises execution of task.
1	Air Vehicle flown with a combination of manual and automatic inputs. On-board sensors operated by HITL.	Data used by HITL.	Decision made by HITL.	HITL authorises execution of task.

Table 1: Author's proposed Levels of autonomy that could be used by UCAS

The author considers the minimum autonomy level a UCAS should operate is Level 3. Levels 1 and 2 are for information only; these levels would best describe current UAS operations, such as Reaper UAS in Afghanistan.

Concern over the ability of autonomous systems to conduct the Find, Fix, Target, Track, Engage, and Assess (F2T2EA) cycle will be assuaged by systems that use Automatic Target Detection (ATD), Automatic Target Initiation (ATI) and Automatic Target Recognition

(ATR) technology.[320] Faster and more-capable computers, communications, and weapon systems contribute to a faster pace in the battlespace and to the requirements for more-rapid decision-making. The proliferation of integrated, accurate sensors provides the opportunity to create a detailed, cohesive picture of the battlespace that could enhance and accelerate combat decisions. Throughout the history of warfare, human senses and reasoning have been the predominant tools used to discriminate friendly forces from targets, and to prioritise and direct strikes against the targets. However, with the volume of data threatening to overwhelm, some assistance is necessary to reduce the requirement for humans to analyse data and make decisions. ATR can exploit sensor data gathering by using algorithms to analyse data. Ideally, ATR algorithms, integrated with high-resolution data and communications fusion, would provide a list of recognised targets, along with sufficient data to assess the associated fratricide and CDE issues.[321] This technology is particularly pertinent to UCAS conducting SEAD and air-to-surface operations, but also has efficacy in air-to-air roles. In the long term, it seems inevitable that autonomous robotic combat systems will be fielded. The USAF certainly plans to do so, with the aim of, '…leverage[ing] a fully autonomous capability, swarming, and Hypersonic technology to put the enemy off balance by being able to almost instantaneously create effects throughout the battlespace'.[322]

The main obstacle to the fielding of truly autonomous strike systems does not seem to be technological maturity. It may not even be unit cost - instead it appears to lie in a cultural disinclination to turn attack decisions over to software algorithms (this is examined later in this chapter). Whether potential adversaries such as China will have similar inhibitions is doubtful.[323] The gap between the US and Russian/Chinese technological capabilities is rapidly closing. Much of the computing processing technology required for advanced weapons and upgrades can be obtained through commercial sources. China has access to

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[320] ATD, ATI and ATR, are the three phases of automatic entity detect, decide if important, then identify. See Jim Schroeder, 'Automatic Target Detection and Recognition Using Synthetic Aperture Radar Imagery', *Cooperative Research Center fo Sensor Signal and Information Processing*, 2011, http://www.ips.gov.au/IPSHosted/NCRS/wars/wars2002/proceedings/invited/print/schroeder.pdf, (accessed 23 August 2010), pp.1-3. For the background to F2T2EA development, see Lt Col John M. Fyfe USAF, *The Evolution of Time Sensitive Targeting: Operation Iraqi Freedom Results and Lessons,* Research Paper 2005-02, College of Aerospace Doctrine, Research and Education: Air University, 2005, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA476994, (accessed 4 November 2012), pp.9-12. The F2T2EA cycle is not a new concept; during the Vietnam War, the US used a similar flow for air-to-air combat engagements – Acquisition, Identification, Challenge, Attack, Position to Fire, Fire, Damage Assessment, Separation - see Attinello, *Air-to-Air Encounters in Southeast Asia: Volume IV: Analyses,* pp.22-23.

[321] Alan J. Vick and others, *Aerospace Operations against Elusive Ground Targets*, Santa Monica: RAND Corporation, CA, 2001, pp.104-105.

[322] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047,* p.50.

[323] Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*, pp.283-284.

these weapons, and significantly, is very adept at reverse engineering, copying these systems and subsequently improving on their design.[324]

Is the confidence placed in the US and its allies' ability to counter emerging threats warranted? There is a school of thought that the F-35 JSF, for example, may be unable to successfully neutralise the new generation of Russian/Chinese fighters that are envisaged in the coming decades. Chris Mills, from *Air Power Australia*, believes, 'The F-22 Raptor is the only US fighter design with the stealth, speed and agility to defeat the new Russian PAK-FA design...'.[325] Dr Carlo Kopp, also from *Air Power Australia,* goes further, opining:

> ....advanced Russian technology exports present a major strategic risk for the US, whether operated by China, or smaller players like Iran or Venezuela. These systems will deny access to most US ISR and combat aircraft, with only the B-2A, the "2018 bomber" and the F-22A designed to penetrate such defences. With its compromised X-band optimised stealth, the F-35 JSF will simply not be survivable in this environment.[326]

These opinions are not aligned with current US military thinking. The JSF published airframe and engine performance is still fundamentally better than any currently proposed UCAS platforms, giving it a higher maximum speed and better manoeuvrability.[327] However, it does not have the performance of the F-22 Raptor. According to Mills, '…the most dangerous situation the US could face, is where the upwardly spiralling…costs of the JSF drain the available resources which are needed to develop the advanced capabilities necessary to counter the new Russian PAK-FA fifth-generation stealth fighter'.[328] He further believes that the West needs to consider, '…long and hard about the PAK-FA, as the current and retrograde F-35 centric future fighter fleet model guarantees certain defeat in future combat'.[329] Whether this view is true or not, it is evident that consideration needs to be given to the type of airframe a UCAV would require, in order to gain control of the air, against an adversary that has reached parity in advanced fighter design and capabilities. It would seem possible that China is likely to achieve this. The recent flight-testing of China's J-20 and J-31 fifth-generation stealth fighters has given some cause for concern in the

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[324] For a view on how China is shrinking the technology gap between itself and the West, particularly the US, see Aaron Friedberg, *A Contest for Supremacy: China, America, and the Struggle for Mastery in Asia*, New York: W. W. Norton & Company, 2011, pp.232-237.

[325] Wg Cdr Chris Mills RAAF, (Retd), 'Air Combat: Russia's PAK-FA versus the F-22 and F-35', *Air Power Australia NOTAM*, 30 March 2009, http://www.ausairpower.net/APA-NOTAM-300309-1.html, (accessed 28 April 2009).

[326] Dr Carlo Kopp, 'The Impact of Russian High Technology Weapons: Transforming the Strategic Balance in Asia', *Air Power Australia Analysis 2008-09*, 12 December 2008, http://www.ausairpower.net/APA-2008-09.html, (accessed 3 May 2009).

[327] See US Department of Defense, 'F-35: Technology', http://www.jsf.mil/f35/f35_technology.htm, (accessed 4 January 2013).

[328] Mills, 'Air Combat: Russia's PAK-FA Verus the F-22 and F-35', *op. cit.*

[329] *ibid.*

West over China's intentions.[330] Although at a very early stage of testing, the mere display of such aircraft adds to the question of why China is developing these, and other sophisticated weapon systems.

Tactical Data-Links

Integrated TDL, which are a fundamental part of NEC, are being utilised by air, sea and land forces - particularly by US forces. UCAS GCS personnel would utilise all aspects of integrated TDL displays and systems, if UCAS were not operating totally autonomously. Most modern western combat aircraft and support assets, such as AWACS, ELINT and AAR aircraft, are fitted with TDL. Ground- and sea-based units, such as ships and radar sites are also fitted. The aim is to allow an integrated Common Operating Picture (COP) to be used by all friendly forces.[331] In warfare, situational awareness is king; TDL harness information from all sources, increasing situational awareness, if integrated correctly, to a level that gives an advantage over an adversary without the same capability. This is, in part, why on day one of any campaign C2 nodes are targeted as a priority.

The picture below is an example of the significant increase in situational awareness gained by the use of TDL. The aircrew of this aircraft, a Tornado F-3, are able to establish where all friendly forces that have TDL are, and are also given the information that these units have; other entities detected by E-3 AWACS are also shown, establishing a COP, which is as accurate and complete as possible. If any known hostile aircraft are detected, these would also be displayed to all users. Ground and sea entities can also be part of the system.[332]

[330] Abdullah, *The Military Balance: 2013*, p.254.

[331] A COP consists of all domains of the battlespace, including land, sea, air and sometimes space. For the significance of TDL, see Anthony Thornborough, *Modern Fighter Aircraft: Technology and Tactics*, Sparkford: Patrick Stephens Ltd, 1995, pp.56-57.

[332] See Reuter, 'Joint Tactical Information Distribution System', pp.16-17.

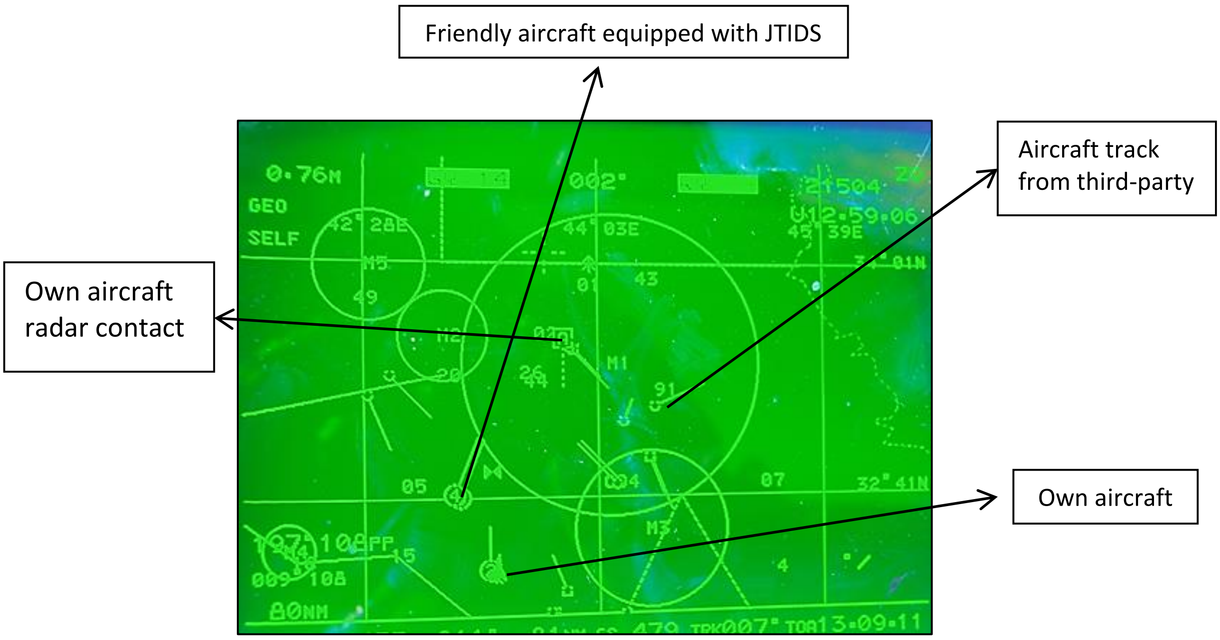

Figure 1: Tornado F-3 JTIDS display.[333]

Advanced TDL displays are in colour, allowing for greater ease of use and discrimination. A level of integration with mapping displays and vastly superior HMI has been achieved because of the evolution of computer processing power. When used autonomously, UCAS and other systems would not need displays – the information produced would be fused through 'objective gateways', such as Battlefield Airborne Communication Node (BACN), allowing decisions to be made much more quickly than if humans were involved.[334] If a HITL was not possible because of loss of communications, then a fused COP could still allow UCAS, and other systems, to operate effectively, until, and if required, communications were re-established. TDL, as part of an NEC, will aid third-party-targeting. The Japanese military refer to this as 'Cloud Shooting' – fighters would fire their AAM using off-board targeting data.[335]

Air-to-Air Refuelling

AAR has enabled air forces to project air power over great distances, sustaining these forces for extended periods, offering huge savings in both manpower and hardware. AAR

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333 This example of a Tornado F-3 Link-16 display is from a sortie during the 2003 Gulf War - from the author's own archive.

334 Defense Industry Daily, 'Bringing Home the BACN to Front-Line Forces', http://www.defenseindustrydaily.com/Bringing-Home-the-BACN-to-Front-Line-Forces-05618/, (accessed 3 April 2012).

335 Bradley Perrett, '6th-Gen on Horizon: Funding Requested to Begin Work on a Japanese Combat Aircraft for the 2030s', *Aviation Week*, 6 September 2010, p.29.

capability is seen as a force multiplier.[336] Unless a platform has the ability to stay airborne long enough to achieve its task unrefuelled, AAR assets will normally be required to extend their time airborne. If AAR is unavailable, or limited, aircraft require the capability to have the range and endurance for the required mission; this will require not only significantly more aircraft, but also radically altered designed characteristics. AAR assets, by virtue of their importance, are normally considered HVAA.

It is anticipated that UCAS will be able to conduct AAR from the normal array of manned AAR assets. Automated tanking from receiving UCAV will be critical to the persistent surveillance and deep-strike capabilities envisioned for UCAS. It is intended that the Northrop Grumman X-47B UCAS-D will conduct trials proving that autonomous aircraft can refuel in flight from the same AAR assets, using the same methods as manned aircraft.[337] The UCAS and manned tanker aircraft exchange position information from on-board global-positioning/inertial-navigation systems via a high-integrity data link. The UCAS calculates its location relative to the tanker and flies itself into formation, from where it is directed, by its GCS or the tanker itself, to the standard refuelling positions used by manned aircraft.[338] As of 2011, more than 10,000 simulations had been conducted before the first X-47B flight, totalling approximately 100,000 hours, including AAR. A surrogate F/A-18D Hornet has been used to conduct trials using the X-47B precision navigation software and hardware. The F/A-18 pilot was hands off, monitoring the procedure. The surrogate F/A-18 performed 36 approaches to a carrier, 16 touch-and-go landings, and six arrested landings. The challenges associated with landing a UCAS aboard a carrier are similar to those in autonomous AAR, such as being able to determine a precise position relative to another moving object, the capability to hold that position, and the proper levels of command and control. A team from Northrop Grumman plans to retrofit and demonstrate this capability by conducting flights with a surrogate, a modified Learjet, in 2014.[339]

While the USAF and USN are developing a common approach to automated refuelling, the Navy version requires an additional step. In the USAF system, the unmanned aircraft navigates itself to the centre of the boom envelope, where the refuelling operator on the tanker takes over and steers the boom into contact with the receiver. In the USN probe-and-drogue system version, the UCAS will navigate itself to where the drogue is expected

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336 For how important the RAF views AAR, see *AP 3002 – Air and Space Warfare*, Chap 8, pp.4-5.

337 Graham Warwick, 'Plug to Play: Automated Aerial Refueling Is Next on X-47B Test Agenda', *Aviation Week and Space Technology*, 5 December 2011, p.11.

338 *ibid.,* pp.11-12.

339 'Autonomous Future: Modeling Simulation Builds Paths for U.S. Unmanned Naval Strike', *DefenseNews*, 28 November 2011, pp.11-12.

to be, where an on-board sensor will guide the probe into contact with the refuelling basket.[340] If these systems work, there is no reason why unmanned AAR assets could not be used, allowing UCAS to refuel UCAS. This capability would further extend the range and persistence of UCAS, particularly if these AAR assets were also survivable in high-threat environments. Extending endurance of aircraft, whether manned or unmanned presents problems not only with fuel requirements and human endurance, but also the oil required for engine systems. The Tornado F-3, for example, could consume one litre of oil per engine per flight hour. Each engine had an oil reservoir capable of holding 10 litres.[341] This gave a maximum sortie length of approximately 10 hours, before an engine would get into the dangerous oil low zone. Engine oil capacity will be a critical node for UCAS operations required to operate over extended periods.

Weapon Systems and Sensors

The types of weapon systems and sensors UCAS will require in the coming decades will be the key to the successful utility of these systems. This may be by kinetic effects, or, ultimately by cyber means. Mostly on-board at present, the trend towards off-board networked systems aiding the establishment of a COP is becoming increasingly important, if not vital.[342] Current UCAS programmes have an array of sensors being considered for employment. These range from Active Electronically Scanned Array (AESA) radars, Synthetic Aperture Radar (SAR), Ground Moving Target Indicator and IR/optical systems.[343] AESA radar technology has revolutionised the capabilities of aircraft and other platforms with which it is fitted. It is not the purpose of this thesis to detail all the technological benefits AESA systems bring, however, it is important to establish an understanding.

The ability of AESA radars to use rapid electronic inertia-less scanning allows for the extremely fast processing of information. The rapid scanning within the search ambit of the system, results in a much quicker target track detection than that of mechanically scanned radar. This permits high accuracy tracking of multiple targets, enabling multiple target engagement while maintaining other functionality. It is not only the superior capability of AESA radars to find and track airborne targets that is revolutionary, but also their capacity

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[340] Warwick, 'Plug to Play: Automated Aerial Refueling Is Next on X-47B Test Agenda', p.12.

[341] See H. Pfoertner and H. Streifinger, *RB199 Engine Oil System Failure by Comparison of Measured and Calculated Oil Consumption*, Munich: Turbo-Union GmbH, 1991, http://www.enginemonitoring.com/publications/aims91.pdf, (accessed 19 August 2012), Para 1 and 2.1, p.7., and Figure 1:, Maximum Oil Consumption at Maximum Dry Thrust', p.22. The oil consumption of military aircraft engines varies depending on the mission.

[342] NEC is the key enabler of a COP.

[343] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 – 2047*, p.60.

to be used in the full EW spectrum. The emergence of AESA radars, and the ability to provide high average power for significant periods, makes them extremely effective.[344] AESA systems offer the opportunity to employ non-kinetic effects. Current AESA radars are focused on detecting and negating cruise missiles, anti-radiation missiles and AAM. AESA radars are particularly effective against AAM because the energy focused on the approaching AAM increases as an inverse square as distance decreases.[345] Fighter aircraft AESA radars use thousands of small transmitters/receivers, each a couple of inches square, which allow the antenna to conduct multiple tasks simultaneously. These include detection of small, even stealthy targets, tracking and communications.[346] Along with the AESA radar's high average power, there are also bandwidth benefits and the ability to utilise flexible waveforms. This means AESA can also be used for EA. Possible AESA techniques for attacking radar systems include burning through the target radar's antenna side-lobes, filter side-lobes, or other known features of the system. AESA transmitters can also be focused on other targets to deliver bursts of RF energy into the electronics of adversary aircraft or computer systems.[347]

AESA radars can also utilise high-power microwave (HPM), which is beginning to emerge as a missile defence system. A handful of F-15C modified with the APG-63(V)2 radars for cruise missile defence and the latest production F/A-18E/F are HPM capable.[348] It is planned to be included in the F/A-22 and B-2 as part of a radar upgrade programme. It is believed that HPM is eventually to be part of a US Navy UCAS payload.[349]

The US defense company Raytheon, plan to build conformal AESA radar that weigh 2 to 5 pounds per square foot and are less than an inch thick. This will allow installation in places

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[344] See Stimson, *op. cit*., pp.577-578. For examples of the application of AESA radars, see Melvin Belcher, 'Phased-Array Pulse-Doppler Radar', in *Airborne Pulsed Doppler Radar,* Second Edition, Guy Morris and Linda Harkness (eds), London: Artech House, 1996, pp.137-142.

[345] David A. Fulghum and Douglas Barrie, 'Directed Energy for Missile Defence: Radar Becomes a Weapon', *Aviation Week,* (2011), http://www.aviationweek.com/aw/jsp_includes/articlePrint.jsp?storyID=news/09055p04.xml&headLine=Directed%20Energy%20for%20Missile%20Defense, (accessed 11 September 2011).

[346] Belcher, *op. cit*., p.136.

[347] 'AESA Radar: Revolutionary Capabilities for Multiple Missions', (2011), http://www.es.northropgrumman.com/solutions/aesaradar/assets/review_aesa.pdf, (accessed 9 September 2011), pp.1-5.

[348] Fulghum and Barrie, 'Directed Energy for Missile Defence: Radar Becomes a Weapon', *op cit.*

[349] *ibid.* A report to the US Congress believes that countries such as China will have programmes developing HPM weapon systems - see Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities - Background Issues for Congress*, Washington, DC, 2008, RL 33153, http://fpc.state.gov/documents/organization/104703.pdf, (accessed 9 September 2010), pp.5 and 101. The US Defense Science Board views that HPM could be utilised in UCAS - see US Defense Science Board, *Report of the Defense Science Board Task Force on Future Strategic Strike Forces,* Washington, DC: Department of Defense, 2004, http://www.bits.de/NRANEU/docs/fssf.pdf, (accessed 1 August 2011), Chap 6, p.9.

inaccessible by current radars. Additionally, Raytheon believes it can expand the capabilities of AESA radar so they can be used by 2015 to feed ISR and other data to other sources at high-speed, and, significantly, installed on UAS.[350] UCAS may become flying antennas, with data imaging and weapons arrays making up the aircraft's skin. Conformal multi-aperture sensors, referred to as smart skins, will be central to UCAS development.[351] AESA radars, or any active radar for that matter, can act as large reflectors, which could compromise RCS. However, frequency selective radomes could be designed to allow only signals to pass through that are in the frequency band of the radar itself; adversary EA would require to be in the same frequency band, which would be hard to achieve. Tunable radomes that can change their filtering characteristics as the AESA changes frequency will further enhance capability.[352] Raytheon's single-curve AESA is the first step in creating antennas that wrap around aircraft, missiles, ships and ground vehicles. These are eventually expected to serve as combination sensors, TDL and EA weapons.[353]

High-energy lasers (HEL) as part of the UCAS weapon system would offer an ideal effector, which would not necessarily be reliant on reloads when depleted. Currently in development, these types of lasers are too large to be incorporated into fighter-sized airframes. However, if these were able to be part of a future UCAV, lasers would offer a potential solution to the kill probability conundrum of AAM (See Chapter 5). Richard Dunn, in *Operational Implications for Laser Weapons*, gives the view that, '…laser weapons offer warfighters opportunities for quick and precise target engagement, flexibility and a light logistics burden'.[354] Dunn believes that, '…warfare could enter the age of laser weapons [by 2016]…'.[355] If utilised, HEL could potentially achieve soft kills, without the need to achieve hard kills, for the majority of scenarios. The mere fact that an adversary can and will use HEL may well cause the recipient to spend great efforts to counter these systems. Major Aaron Angell USMC, describes how HEL equipped aircraft might be employed:

> The ability of aircraft to conduct counter-air warfare will be greatly enhanced by a HEL weapon. It could provide a counter-air capability that operates distinctly from the primary mission of the aircraft and pilot… while a pilot is conducting his assigned aviation mission…a

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[350] Colin Clark, 'UAVs Next Step for AESA Radar', *DoD Buzz: Online Defense and Acquisition Journal*, 21 July 2010, http://www.dodbuzz.com/2010/07/21/uavs-next-step-for-aesa-radar/, (accessed 14 October 2011).

[351] Douglas Barrie, David A. Fulghum, and Robert Wall, 'Sensors vs. Airframes', *Aviation Week and Space Technology*, 30 October 2006, p.46.

[352] *ibid.,* p.47.

[353] David A. Fulghum, 'Ruling the Changes', *Aviation Week and Space Tecnology*, 30 October 2006, p.49.

[354] Richard J. Dunn, 'Operational Implications of Laser Weapons', *Northrop Grumman - Analysis Center Papers* , 2006, http://www.northropgrumman.com/analysis-center/paper/assets/Operational_Implications_of_La.pdf, (accessed 4 October 2010), p.10.

[355] *ibid*., pp.1-4.

> HEL weapon could automatically identify, acquire, target, and engage an enemy missile or aircraft.[356]

AAM are being considered for use on UCAS. The USAF and the US Missile Defense Agency, allied with Raytheon, are developing AESA radar systems in conjunction with an extended range AAM, as part of their Network-Centric Airborne Defense Element (NCADE), aiming to engage ballistic missiles. Initially to be carried by F-22, Philip Pagliara, Raytheon Missile Systems' programme manager for NCADE, believes UCAS could be used as effectively. According to Pagliara, '"…a longer-term solution would be to put radars and missiles on larger unmanned aircraft…The operational concept for both manned and unmanned is similar"'.[357] If UCAS were fielded today, their killing payload would consist of AAM. If AAM kill probability was not to an acceptable level, and not enough could be carried, then other negating mechanisms would be required. It is the author's view, that in any case, appropriate effecters that do not suffer a limit on expenditure will be required.

Countermeasures

Countermeasures to defeat or confuse the components comprising a sophisticated IADS will be a critical element of any future UCAS. These will range from EA systems, either utilised through AESA radars, and/or other systems. The full panoply of countermeasures includes DRFM jammers, towed radar decoys, expendable radar decoys, stand-in jammers to defeat RF missile systems, and Directed Infrared Countermeasures (DIRCM) and flares to defeat IR missile systems. The aim of a DIRCM missile jammer is to radiate more modulated IR than the seeker receives from the aircraft's heat sources.[358] DRFM technology has transformed the ability to counter adversary radar defence systems. A DRFM countermeasures system can duplicate an incoming signal from enemy radars by converting it from analogue to digital and back again. DRFM jammers then modify the digital duplicate so that the manipulated signal will be coherent with the threat radar. This signal manipulation can deceive threat radars by altering the target's apparent RCS, range, velocity, and angle.[359] Added, would be a requirement to counter laser and HPM systems. Active and passive countermeasures are inherently costly and difficult to implement into manned aircraft and stealthy aircraft in particular. The process of defeating any missile system involves two necessary tasks, detecting missile launch, and deploying

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[356] Major Aaron Angell, 'The High-Energy Laser: Tomorrow's Weapon to Improve Force Protection', *National Defense University Press*, no. 64, 2012, p.120.

[357] David A. Fulghum, 'Boost-Phase Battles', *Aviation Week and Space Technology*, 28 June 2010, p.54.

[358] RAF Air Warfare Centre, *Infrared Countermeasures Handbook*, p.25.

[359] See Schleher, *op. cit*., pp.293-294.

countermeasures to defeat the missile guidance system. Currently, classic detection techniques rely either on visual acquisition or aircraft sensors mounted on the aircraft. Reliable missile launch detection, via a Missile Approach Warner System (MAWS), is a technological challenge, but offers a viable solution. MAWS forms part of a DIRCM system.[360]

If a UCAS is to be stealthy, and required to operate in highly sophisticated IADS, the essential requirement of the surface of the UCAV airframe to be smooth, with very few, if any protrusions, will take priority. A UCAV would also likely carry the same EA system fitted to manned fighters. For example, the US Navy is developing the Next Generation Jammer (NGJ), which could be utilised by UCAS.[361] A balance may be required between the necessity for absolute stealth and countermeasure capability. The need to have fitted internally, or as a conformal part of the UCAV airframe, Closed-Loop DIRCM jammers, lasers, AAM, HPM and the like, will be difficult to align with other requirements. It can never be assumed that an aircraft is invulnerable to missile, laser or HPM attack, therefore, negating systems and countermeasures are essential, as is defence against cyber-attack; this is examined in Chapter 4.

The Law of Armed Conflict, Ethics, and Employment of UCAS

The development of UCAS in future warfare requires scrutiny to ensure compliance with international laws, both in practice and ethically. The current employment of UAS has raised issues over the legality of their use. The future utility of UCAS will need to be examined to ensure that the LOAC is adhered to, not least, if these systems are employed autonomously. Authorising an unmanned system to make combat decisions autonomously will be dependent upon the political and military cadre resolving legal and ethical issues. These include the appropriateness of unmanned systems having this capability, under what circumstances these should be utilised, where responsibility lies for mishaps, and what limitations should be placed upon the autonomy of such systems. International laws and treaties in modern warfare govern the use of weapons. Individual nations interpret their political, legal and operational constraints, which dictate the ROE for their forces, specific to each operation. Different ROE may be set for different phases and locations during a campaign. The ROE set clear criteria for the decisions made by humans in the command chain. Could these decisions be made autonomously by 'systems' used by UCAS? For

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[360] RAF Air Warfare Centre, *Infrared Countermeasures Handbook*, pp.25-26.

[361] See John Haystead, 'NGJ - Advanced Tactical Jamming for the Next-Generation Warfare', *The Journal of Electronic Defense* 35, no. 8, 2012, p.43.

armed autonomous systems, the critical issue is the ability for the weapon to discriminate a legal target. There is considerable discussion within the military, media and academic institutions on the ethical and legal implications of the current use of UAS, and the future utility of UCAS.[362] The two issues are essentially separate disciplines, but ethical, sometimes referred to as moral, issues do enter into the realm of the laws of war, at times.[363] Reviewing existing opinions on the legal and ethical issues will allow an understanding of the current concerns, and whether these will impact the development of UCAS.

In a report published in 2011, the UK MOD offers the view that policy makers need to be aware of the potential legal issues involved in UAS procurement and use.[364] This is a legal requirement.[365] Whether UCAS will operate with a HITL, HOTL, or autonomously, seems to be causing the most concern. Currently, UAS operate with a HITL. Future UAS/UCAS may not follow this *modus operandi*. P. W. Singer in, *Wired for War: The Robotics Revolution and Conflict in the 21st Century,* discusses the issue of autonomy and keeping a HITL. Singer gives a number of examples of both military and civilian professionals, who view that keeping a HITL will always be required.[366] The author's own survey, however, indicates this is not necessarily the majority view among military professionals, and civilians. Detailed in Chapter 1, analysis of the responses to the questionnaire sought views on whether ethical or political constraints should affect future UCAS doctrine; these views confirmed that there is little ethical compunction against using UCAS, autonomously if required, with 86% of interviewees having no concerns.[367] The thoughts from a political perspective, however, indicate that it is highly likely that politicians would be reticent in authorising the use of autonomous unmanned systems, unless used legally. A somewhat

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362 There is a large corpus of work on these issues. For an excellent discussion on the legality of the current use of UAS, see Michael Schmitt, 'Unmanned Combat Aicraft Systems (Armed Drones) and International Humanitarian Law: Simplifying the Oft Benighted Debate', *Boston University International Law Journal* 30, no. 3, 2012,. pp.595-619. Schmitt, who is Chairman, International Law Department, US Naval War College, views that there are very few legal issues unique to the employment of UCAS on the battlefield.

363 Armin Krishnan discusses the differences between what is legal and ethical in war - see Armin Krishnan, *Killer Robots: Legality and Ethicality of Autonomous Weapons*, Farnham: Ashgate Publishing Limited, 2009, pp.117-118. Legal and ethical issues are examined later in this section.

364 *Joint Doctrine Note 2/11*, *op. cit.,* Para 508, p.5-4. From an RAF perspective, for a legal viewpoint on the use of UAS, see Wg Cdr Allison Mardell RAF, 'Unmanned Aerial Vehicles - the Legal Perspective', in Air Power - UAVs: The Wider Context, Owen Barnes (ed), Directorate of Defence Studies, 2009, pp.68-82.

365 *Joint Doctrine Note 2/11*, *op. cit*., p.5-2, para 503. A US DoD Directive, for example, details the policy for the development of autonomous weapon systems. This stipulates very clearly that those who authorise the use of autonomous weapon systems, including unmanned platforms, must do so in accordance with the LOAC, applicable treaties and ROE - see US Department of Defense, 'Directive Number 3000.09: Autonomy in Weapon Systems', 21 November 2012, http://www.dtic.mil/whs/directives/corres/pdf/300009p.pdf, (accessed 9 February 2013), p.2, para 4(b).

366 See Singer, *Wired for War,* pp.123-124.

367 See Appendix H.

obvious view, some would say. Nonetheless, these issues are relevant, and it does not take much sagacity to see the actual benefits from conducting in-depth analysis.[368]

The Law of Armed Conflict

The LOAC, also known as Customary International Humanitarian Law (CIHL), is part of that body of international law that governs the relations between states; it is derived from two main sources of international law - treaty law and customary law (rules developed from the practice of states which are binding on all states).[369] Although debate continues over whether CIHL, the Law of War and the LOAC, are the same discipline, Professor Gary Solis best sums up the opinions: 'Whether called the law of war, IHL, or LOAC, the goal is to confine fighting as closely as possible to combatants and to spare noncombatants; to target those things having a military need for destruction and sparing property not necessary to achieve the military ends of the conflict'.[370] The LOAC regulates the rights and duties of the belligerents in time of armed conflict. It seeks to protect combatants and non-combatants from unnecessary suffering, and to provide safeguards for civilians and persons who fall into the hands of an adversary.[371] The Laws of War are divided into three basic categories, the first two being of established acceptance, with the third forming a relatively new emphasis; these are: *jus ad bellum*: the law concerning acceptable justifications to use armed force and declare war, and *jus in bello*: the law concerning acceptable conduct in war, once it has begun.[372] *Jus post bellum*, is the law concerning acceptable conduct following the official or declared end of a war.[373] *Jus in bello* tradition asserts that there are two external rules: 'Proportionality', and 'Discrimination and Non-Combatant Immunity'.[374] Non-Combatant Immunity means that non-combatants must not be intentionally killed or harmed. There are other principles; Joint Services Publication (JSP) 383 describes the four customary principles of the LOAC as:

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[368] Lin, Bekey, and Abney, *op. cit.,* p.84. For a contemporary view on these issues, see, Krishnan, *op. cit.,* pp.89-144.

[369]Joint Doctrine and Concepts Centre, *JSP 383: The Joint Service Manual of the Law of Armed Conflict*, Shrivenham: UK Ministry of Defence, 2004, p.2.

[370] Gary D. Solis, *The Law of Armed Conflict: International Humanitarian Law in War*, Cambridge: Cambridge University Press, 2010). p.27.

[371] *JSP 383, op. cit.,* p.21.

[372] International Committee for the Red Cross, 'IHL and Other Legal Regimes - Jus Ad Bellm and Jus in Bello', (2010), http://www.icrc.org/eng/war-and-law/ihl-other-legal-regmies/jus-in-bello-jus-ad-bellum/overview-jus-ad-bellum-jus-in-bello.htm, (accessed 17 July 2009). See also, Geoffrey Best, *Humanity in Warfare*, New York: Columbia Press, 1980, p.8.

[373] For a discussion on *jus post bellum,* see Brian Orend, 'Jus Post Bellum: The Perspective of a Just-War Theorist', *Leiden Journal of International Law* 20, no. 3, 2007, pp.571-591.

[374] Lin, Bekey, and Abney, *op. cit.,* pp.49–50.

Military Necessity: Military necessity permits a state engaged in an armed conflict to use only that degree and kind of force, not otherwise prohibited by the law of armed conflict, that is required in order to achieve the legitimate purpose of the conflict, namely the complete or partial submission of the enemy at the earliest possible moment with the minimum expenditure of life and resources.[375] Humanity: The principle of humanity forbids the infliction of suffering, injury or destruction not actually necessary for the accomplishment of legitimate military purpose.[376] Distinction: Since military operations are to be conducted only against the enemy's armed forces and military objectives, there must be a clear distinction between the armed forces and civilians, or between combatants and noncombatants, and between objects that might legitimately be attacked and those that are protected from attack.[377] Proportionality: The principle of proportionality requires that the losses resulting from a military action should not be excessive in relation to the expected military advantage.[378]

Proportionality and Distinction are fundamentals of the LOAC, and will likely remain so. The current law on targeting (Distinction) is contained within the 1977 Additional Protocol 1 (AP1) to the Geneva Convention of 1949. The basic rule, encapsulating the principle of distinction, is contained in Article 48 of AP1:

> In order to ensure respect for and protection of the civilian population and civilian objects, the Parties to the conflict shall at all times distinguish between the civilian population and combatants and between civilian objects and military objects and accordingly shall direct their operations only against military objectives.[379]

AP1 to the Geneva Convention represented an unprecedented change to the protection of civilians in the law of armed conflict.[380] Unlike other binding documents of the LOAC in the past, AP1 explicitly stipulates the protection of civilians.[381] It is argued by some theorists that in contemporary armed conflicts, especially in internal wars, the principle of civilian protection in its most elementary form continues to be violated.[382] The Doctrine of Double Effect (DDE), originating from natural ethical law, does, nonetheless, allow for collateral damage, that is, the killing of civilians, in certain circumstances. DDE may be permissible, even if it is foreseen that it will cause a bad effect.[383] The Philosopher Joseph Mangan is credited with formulating the DDE, with his seminal 1949 essay, *An Historical Analysis of the Principle of Double Effect,* Mangan offered the following thoughts:

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[375] *JSP 383*, *op. cit*., p.22, para 2.2.

[376] *ibid.,* p.23, para 2.4.

[377] *ibid.,* p.24, para 2.5.

[378] *ibid.,* p.25, para 2.6. For a comprehensive explanation of the 'Four Principles' of the LOAC, see Solis, *op. cit*., pp.250-285.

[379] Howard M. Hensel (ed), *The Law of Armed Conflict*, Aldershot: Ashgate Publishing Ltd, 2007, p.114 See also, Henckaerts and Doswald-Beck, *op. cit*., p.51.

[380] See International Committee of the Red Cross, *Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977*, ICRC, 1977.

[381] Hensel, *op. cit*., p.114.

[382] *ibid*., pp.102-103.

[383] Lin, Bekey, and Abney, *op. cit.,* p.51.

> It is lawful to actuate a morally good or indifferent cause from which will follow two effects, one good and the other evil, if there is a proportionately serious reason, and the ultimate end of the agent is good, and the evil effect is not the means to the good effect. The reason for this principle is that such an action could be unlawful only from the intention of the evil effect, or from the very actuating of the cause itself, or from the foreseeing of the evil effect. But the action is not unlawful under any one of these headings.[384]

DDE is particularly pertinent when considering UAS use against terrorist and insurgent groups, whom may be using civilians as human shields. This does not mean, however, that states will always fall back on this principle, particularly, in low-intensity operations. It is dependent on the importance of the mission, ultimately.

The International Committee of the Red Cross (ICRC) has published 161 rules that apply to the LOAC.[385] When a weapon system is being procured for use, countries must ensure that these principles are taken into account. Perhaps the most pertinent rules when considering the developmental path of UCAS are Rules 15, 16, 17 and 151. Rule 15 - *Precautions in Attack*, states: 'In the conduct of military operations, constant care must be taken to spare the civilian population, civilians and civilian objects. All feasible precautions must be taken to avoid, and in any event to minimize, incidental loss of civilian life, injury to civilians and damage to civilian objects'.[386] Rule 16 pertains to *Target Verification:* 'Each party to the conflict must do everything feasible to verify that targets are military objectives'.[387] Rule 17, *Choice of Means and Methods of Warfare*, confers responsibility by the following: 'Each party to the conflict must take all feasible precautions in the choice of means and methods of warfare with a view to avoiding, and in any event to minimizing, incidental loss of civilian life, injury to civilians and damage to civilian objects'.[388] Binding these rules together is Rule 151, *Individual Responsibility*: 'Individuals are criminally responsible for war crimes they commit'.[389] These rules are particularly relevant, with the potential for UCAS operating autonomously to deliver weapons.

Within the LOAC, the term combatant applies to those persons who have the right under international law to participate in armed conflict. These persons include members of the regular armed forces (except medical personnel, chaplains, civil defence personnel, and

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[384] Joseph T. Mangan, 'An Historical Analysis of the Principle of Double Effect', *Theological Studies,* 10, 1949, http://philpapers.org/archive/MANAHA-2, (accessed, 18 October 2012), p.60.

[385] For all 161 rules, see Henckaerts and Doswald-Beck, *op. cit.*

[386] *ibid.,* pp.51-55.

[387] *ibid*., pp.55-56.

[388] *ibid*., pp.56-58.

[389] *ibid*., pp.551-555.

members of the armed forces who have acquired civil defence status) and irregular forces, which carry their arms openly and distinguish themselves from the civilian population.[390] In general, civilians are considered non-combatants. Since only combatants may lawfully participate directly in armed conflict, non-combatants who do so are acting unlawfully and are considered illegal combatants. More importantly, Rule 106 – *Combatants and Prisoner-of-War Status,* covers civilian personnel who are illegal combatants; these constitute a legitimate military target, which can be legally prosecuted for their wartime actions, and do not have the same prisoner of war protections as lawful combatants.[391] This may apply, for example, to the software engineers of UCAS.

Effect on Middle East and Arab Public Opinion

The current debate over the legal and ethical issues of the use of UAS is worth examining, particularly with regard to its relevance to UCAS. Not least, current US UAS operations against targeted 'terrorists' has amplified the arguments over the lawful use of UAS. In 2009, President Obama authorised the use of UAS to conduct targeted-assassination missions against suspect terrorists, not only in Afghanistan and Iraq, but also Pakistan and Yemen.[392] The continued use of US UAS on these types of missions has caused some disquiet. In a letter to *The Times*, fourteen distinguished historians detailed their belief that the use of, '…UAS 'drones' in Afghanistan and Pakistan, is in violation of international law, as there is no state of war with the communities involved and insufficient care has been taken to ensure that there is no negligent harm to civilians…'.[393] They believe their use is, '…likely to engender hostility and alienation, and will do nothing to improve the population's perception of the American and British forces responsible'.[394] While their first concern is arguable (examined later in this section), affected civilian public opinion is certainly of concern. In Arab culture, remote means of conducting warfare are seen as cowardly. It is also argued that the civilian deaths caused

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[390] See Rule 3 – *ibid*., pp.11-14.

[391] *ibid.,* pp.384-389. This principle was reinforced during World War II, when at the Nuremberg Trials, it was ruled that those that fought in Yugoslavia and Greece against the 'occupying power', which was Germany, were illegal combatants – see, Judge Wennerstrum, 'Opinion and Judgement of Military Tribunal V', in *In the Matter of the United States of America against Wilhelm List and others,* Nuernberg: 19 February 1948, http://www.worldcourts.com/ildc/eng/decisions/1948.02.19_United_States_v_List1.pdf, (accessed 2 November 2012), p.1245.

[392] Tony Allen-Mills, 'Obama Faces Flak over Remote-Control Killings', *The Sunday Times*, 9 August 2009, p.27.

[393] Professor Sir Richard Evans, Professor Richard Overy, and Professor Richard Toye, 'Changing Policy on Drone Attacks', *The Times*, 7 December 2012, p.14.

[394] *ibid*.

by the use of UAS creates more militants than those eradicated.[395] Terrorists, and frequently some of the civilian population, perceive the use of new technologies, such as UAS, as evil.[396] The Taliban claimed that their 2009 attack on the Lahore Police Academy in Pakistan was in direct retaliation for Predator UAS strikes. While it is somewhat understandable that civilians in countries such as Pakistan may see the use of UAS as 'unfair', it is completely perverse that terrorist groups, such as the Taliban, do. The failure of the Taliban to meet their reciprocal responsibilities under the LOAC, by intentionally using voluntary human shields, allows these civilians to be targeted.[397] This type of targeting would only be used in extremis, but would be consistent within the DDE.

Opinions differ; there is an argument that the use of UAS, and the associated weapons and sensors technology, will allow for greater discrimination and the prevention of collateral damage.[398] There is also a view that to rule out the legality of the targeting of terrorists on foreign territories is at odds with the obligations of nation-states to protect their citizens from terrorist attacks.[399] Andrew Orr, in *Unmanned, Unprecedented, and Unresolved: The Status of American Drone Strikes under International Law*, argues persuasively that the use of UAS by the US in Pakistan adheres to the LOAC, although he acknowledges that the facts of the engagements remain classified.[400]

In May 2013, in a speech at the National Defense University, President Obama spoke about the use of 'Drones':

> Where foreign governments cannot or will not effectively stop terrorism in their territory, the primary alternative to targeted lethal action would be the use of conventional military options. As I've already said, even small special operations carry enormous risks. Conventional airpower or missiles are far less precise than drones, and are likely to cause more civilian casualties and more local outrage. And invasions of these territories lead us to be viewed as occupying armies, unleash a torrent of unintended consequences, are

[395] Andrew Callam, 'Drone Wars: Armed Unmanned Aerial Vechicles', *International Affairs Review* XVIII, no 3, 2010, http://www.iar-gwu.org/node/144, (accessed 7 June 2013).

[396] *ibid.*

[397] Chris Jenks, 'Law from Above: Unmanned Aerial Systems, Use of Force, and the Law of Armed Conflict', *North Dakota Law Review* 85, 2009, p.669. For an analysis of reciprocity and the LOAC, see generally, Sean Watts, 'Reciprocity and the Law of War', *Harvard International Law Journal* 50, no. 2, 2009, pp.365-434.

[398] For example, see Colm McKeogh, *Innocent Civilians: The Morality of Killing in War*, Basingstoke: Palgrave, 2001, p.141.

[399] For a discussion on whether such killings are justified under CIHL, see Michael Ramsden, 'Targeted Killings and International Rights Law: The Case of Anwar Al-Awlaki', *Journal of Conflict &Security Law* 16, no. 2, 2011, pp.385-406.

[400] See generally, Andrew C. Orr, 'Unmanned, Unprecedented, and Unresolved: The Status of American Drone Strikes under International Law', *Cornell International Law Journal* 44, 2011, pp.729-752.

> difficult to contain, result in large numbers of civilian casualties and ultimately empower those who thrive on violent conflict.[401]

Understanding the feelings that the use of UAS can engender in the civilian population of countries affected, Obama emphasises the legality of their use, and also the proportionality and accuracy they offer. This speech is a clear indication that the US will continue with the use of UAS.

International Committee of the Red Cross in Relation to UAS/UCAS

At the 2011 ICRC forum, 'New Weapon Technologies and IHL', Dr Jakob Kellenberg, President of the ICRC, commented on robotic weapon systems, highlighting a number of issues, the foremost being the challenge of ensuring automated systems are capable of the level of discrimination required by IHL. Kellenberg believes the deployment of such systems would reflect a paradigm shift and a major change in the conduct of hostilities, but would also raise a series of fundamental legal and ethical issues. Kellenberg's opinion, however, is that automated weapon systems may actually be more ethical and operate far more cautiously on the battlefield than a human being. In certain cases, he believes, the deployment of remote-controlled or autonomous weapon systems might cause fewer civilian casualties and less damage compared to the use of conventional weapons. Because these types of weapon systems are deployed from a safe distance, with time to choose targets carefully, it may be easier to avoid civilian collateral damage. It could even be argued that the LOAC would require that a commander consider whether the use of autonomous systems may be best practice in achieving the military objective.[402] At the same forum, Dr Philip Spoerri, Director for International Law and Cooperation, ICRC, emphasised the difficulties facing the use of autonomous weapon systems, particularly, individual responsibility:

> ….Whether new technologies will reduce our capacity to allocate responsibility and accountability for violations remains to be seen…it is worth recalling that international humanitarian law parties to conflicts (states and organised armed groups) and international criminal law binds individuals...I am not convinced that we have reached the end of accountability with autonomous weapons. Even if artificial intelligence were to be achieved and autonomous systems deployed in armed conflicts, would it not always be the case that any robot is at some point switched on by a human being? If that is the case, then that individual –

[401] President Barak Obama, 'President Obama Speaks on the U.S. Counterterrorism Strategy', 23 May 2013, http://www.whitehouse.gov/photos-and-video/video/2013/05/23/president-obama-speaks-us-counterterrorism-strategy#transcript, (accessed 28 May 2013).

[402] Dr Jakob Kellenberger, 'International Humanitarian Law and New Weapon Technologies', 2011, http://www.icrc.org/eng/resources/documents/statement/new-weapon-technologies-statement-2011-09-08.htm, (accessed 3 February 2012).

> and the party to the conflict - is responsible for the decision, however remote in time or space the weapon might have been deployed from the moment of the attack.[403]

Both Kellenbeg and Spoerri raise germane points. Developing autonomous (highly automated) weapon systems, requires a rigorous audit of likely legal issues. Research is on-going, for example, Tony Gillespie and Robin West, in *The International C2 Journal: Requirements for Autonomous Unmanned Air Systems set by Legal Issues*, propose an approach for developing these systems within current legal constraints. They consider that there are two approaches to aligning technology and the law: fitting emerging technologies into the law, and articulating the legal and ethical constraints as requirements, which would then determine design protocols. The first approach is traditional, with the legal considerations placing limitations on the operational exploitation of any military capability. The second approach uses systems and capability engineering techniques, which provide a procedure to turn constraints into design requirements for unmanned air systems.[404]

An autonomous system will use machine-based logic to make command decisions that are currently made by humans. Gillespie and West believe it should be possible to develop systems using technologies which are based on an approach that turns qualitative criteria into autonomous quantitative ones; they describe how a three-part model, developed by Joanne Thoms, could be used to derive a method to convert the human role to one provided by an autonomous decision making system.[405] The three cognitive capabilities are: *Awareness*: perceiving the current operational position and context. This is the assimilation of all available sensors and other information relevant to the UAS and its mission. *Understanding*: recognising the relationships in the information, and their significance. *Deliberation*: choosing between the various options available, based on an understanding of them and their consequences.[406] It includes making the decision within the known constraints and acting on it; that is, a decision point in the command chain.[407] Gillespie and West suggest using this three-component model of the decision-making process to establish the technical requirements for autonomous decision-making systems and the implications for technology development.[408] This method could provide a robust means of conducting evaluation of UCAS.

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403 Dr Philip Spoerri, 'Round Table on New Weapon Technologies and IHL - Conclusions', 2011, http://www.icrc.org/eng/resources/documents/statement/new-weapon-technologies-statement-2011-09-13.htm, (accessed 3 February 2012).

404 Gillespie and West, *op. cit*., p.3.

405 *ibid*., pp.15-16.

406 Joanne Lesley Thoms, *Human Centric Systems Engineering,* University of Bath, 2009, pp.70-76.

407 Tony Gillespie and West, *op. cit*., pp.15-16.

408 *ibid.,* p.1.

William Boothby, in *Weapons and the Law of Armed Conflict*, details the LOAC issues that are pertinent to the use of Unmanned Combat Vehicles (UCV). Air Commodore Boothby RAF (Retd), was Deputy Director of Legal Services for the RAF until 2011. Boothby describes UCV, '…as unmanned air, land, or maritime vehicles of any size which either carry and deliver force, which may have been deployed from another platform, to a target'.[409] Boothby emphasises that the important question is the ability of the vehicle to direct a weapon to a target, whether it took the weapon there or not.[410]

> The mere fact an unmanned vehicle is used to fire a weapon does not raise relevant issues if, for example, the technology permits a person to review available information and requires that person to review available information and requires that person to make a decision in advance as to whether the particular attack goes ahead.[411]

If the system has an autonomous attack capability, Boothby states that the legal reviewer, that is, the person responsible for advising the authoriser on the legal aspects of the mission:

> …is therefore concerned to establish whether the particular technology governing the vehicle and its prosecution of autonomous attacks is such that those attacks will properly discriminate in the manner provided for in article 51 or, for states not party to AP1, as required by customary law principles….His task…is to assess whether the system is capable, in the circumstances of intended use, of being used in a discriminating way…[412]

Article 57 of AP1 details the considerations required for sparing civilians and civilian objects. Article 57(2)(a) details the precautions that must be taken in respect of attacks, addressing the requirements for, 'those who plan or decide upon an attack'.[413] A problem arises for the reviewer when autonomous technology is employed. The reviewer is required to determine whether Article 57(2)(a) can be adhered to. A HITL, Boothby believes, able to monitor systems, and countermand an attack decision, if required, would satisfy the LOAC.[414] JDN 2/11 states that, 'Legal responsibility for any military activity remains with the last person to issue the command authorising a specific activity'.[415] However, Boothby gives the legal opinion that if a human was not in the loop, the use of

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[409] William H. Boothby, *Weapons and the Law of Armed Conflict*, Oxford: Oxford University Press, 2009, p.230.

[410] See *ibid*., p.230.

[411] *ibid*., p.231.

[412] *ibid*. For an opinion on the legal considerations for the employment of autonomous systems, see Singer, *Wired for War,* pp. 407-411,

[413] International Committee of the Red Cross, 'Protocol Additional to the Geneva Coventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol 1), 8 June 1977: Precautions in Attack - Article 57', http://www.icrc.org/applic/ihl/ihl.nsf/ART/470-750073?OpenDocument, (accessed 19 May 2011).

[414] Boothby, *op. cit*., p.233.

[415] *Joint Doctrine Note 2/11, Unmanned Aircraft Systems: Terminology, Definitions and Classification*, p.5-5.

autonomous weapons would still be within the principle of distinction, if appropriate technology was used. Boothby argues that by using software algorithms and artificial intelligence, attacks may be restricted to legitimate objects.[416] Wg Cdr Mardell, an RAF lawyer, is also of the opinion that, '…providing the relevant decisions are made, it does not seem to matter whether this process is undertaken by humans or machines'.[417]

UAS are now accepted as part of the military inventory, with their current C2 structures ensuring that ROE are met with HITL at the critical points in the decision cycle. Research programmes around the world are developing ways of introducing autonomy into the decision processes of UAS; the next step is UCAS. UCAS may include several UCAV operating together making cooperative decisions.[418] Authorisation of weapon release is a clear example where the current position of human intervention may be expected to continue for some time.[419] However, technology will become available, for example, to task a UCAS to survey a given area, looking for particular target types, and destroying them when found, without reference to a human commander - a system with the capability of delivering effects autonomously.[420]

Articles 13 and 16 of The Hague Rules of Air Warfare, detail that only military aircraft can exercise belligerent rights.[421] UCAV are defined as military aircraft.[422] They can be used autonomously, with caveats:

> UCAVs…whether remotely piloted or acting autonomously, may engage in attacks as long as they qualify as military aircraft. Autonomous action means that the unmanned aircraft has sensors and an onboard data processing capability to make decisions to attack according to a computer program. The sensors and computer programs must be able to distinguish between military objectives and civilian objects, as well as between civilians and combatants.[423]

Boothby believes that the system is capable of being used within the principle of distinction, although there may remain a legal requirement for a person to remain in the decision loop,

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[416] Boothby, *op. cit.,* p.233.

[417] Mardell, *op. cit*., p.72.

[418] For example, see Alec Banks, Jonathan Vincent, and Keith Phalp, 'Particle Swarm Guidance System for Autonomous Unmanned Aerial Vehicles in an Air Defence Role', *The Journal of Navigation* 61, no. 1, 2008, pp.9-29.

[419] The UK *Taranis* programme, for example, is exploring this capability, but with the emphasis, currently, on having a HITL to give authorisation, even though it may be capable of doing so autonomously - see QinetiQ, 'UK Taranis Passes UAV Passes First Major Milestone', *op. cit*.

[420] See Polat Cevik and others, 'The Small and Silent Force Multiplier: A Swarm UAV-Electronic Attack', *Journal of Intelligent Robotic Systems* 70, 2013, pp.595-608.

[421] Commission of Jurists at the Hague, 'Rules Concerning the Control of Wireless Telegraphy in Time of War and Air Warfare', (1923), http://www.icrc.org/ihl.nsf/FULL/275, (accessed 9 September 2012).

[422] *Commentary on the HPCR Manual on International Law Applicable to Air and Missile Warfare*, p.100, para II, 17(a).

[423] *ibid*., p.101, para 3.

unless, '…it is possible at the sortie planning stage to take precautions in attack, which will remain valid throughout the period of UCV search to an acceptable level of confidence…for example, in areas remote from civilians…'.[424] This is particularly pertinent to counter-air operations.[425] Opinion will continue to remain divided. However, in the area of gaining control of the air, certainly in air-to-air engagements, the issue of collateral damage is treated differently from some other types of attacks. In law, current counter-air air-to-air practice is not required to take into account collateral damage from shot down armed military aircraft. The *HPCR Manual on International Law Applicable to Air and Missile Warfare* states:

> Some members of the Group of Experts believed that consideration must also be given to the possibility that aircraft that are shot down in the air may cause collateral damage on the ground…The majority of the Group of Experts rejected this assertion, based upon the general impracticality of factoring in such eventual collateral damage during an air-to-air engagement. However, the majority of the Group of Experts conceded that there may be exceptional circumstances in some rare instances of air supremacy. In these circumstances, when a military aircraft intends to shoot down an aircraft — other than an armed military aircraft — over densely populated areas, the attack ought to be delayed in order to avoid — or, in any event, to minimize — collateral damage.[426]

Certain counter-air operations will be conducted entirely over the sea, minimising the chances of any collateral damage to virtually to nil. Nonetheless, even for counter-air operations conducted over, or near, populated areas, collateral damage is not a legal issue. This removes any legal arguments against using UCAS in an air-to-air role, as far as collateral damage is concerned. That said, the normal laws of war will still apply, whether manned, unmanned, or autonomous unmanned systems are used.[427]

The LOAC already allows for the use of autonomous UCAS, within the constraints adumbrated. Ultimately, individual states are responsible for ensuring that weapon developments adhere to Article 36 of the 1977 Additional Protocol I to the Geneva Conventions of 1949. Article 36 requires each State Party to ensure that the use of any new weapons, means or methods of warfare that it studies, develops, acquires or adopts

[424] Boothby, *op. cit.,* p.233.

[425] Dr Marco Roscini, Reader in International Law, University of Westminster, believes that a fully autonomous UAS/UCAS could meet the principle of proportionality, particularly, in areas with little, or no, civilians - see Professor Christopher Coker and Dr Marco Roscini, 'Transcript - Drones: The Future of War?', 8 April 2013, http://www.chathamhouse.org/sites/default/files/public/Meetings/Meeting%20Transcripts/080413Drones.pdf, (accessed 12 April 2013), p.10.

[426] *Ibid*., p.136.

[427] See Coker and Roscini, *op. cit*., pp.8-12, for an extremely well balanced discussion on the legal aspects of the use of UAS.

comply with the LOAC.[428] In general, once a system has been released into service, legal responsibility will always remain with the person who issued the command to the UAS. If autonomous systems could not be employed for long-endurance and complex scenarios, without a HITL or HOTL, many of the advantages of UCAS would be lost.

Ethics

There is an increasingly large source of literature on the ethics of using UAS.[429] There are arguments both for and against the use of UAS being ethical. Arguments against their use include the view that these systems fail a *jus ad bellum* test, because political leaders might be more inclined to wage war; robotic soldiers could lower barriers to entering a war, since they would reduce casualties among human soldiers.[430] Some object to their use because they would potentially make war relatively risk-free. They view that autonomous military systems, with the potential for fewer human casualties, will make war less horrific, and therefore more likely.[431] P. W. Singer certainly believes so, opining that, '…robots may entail a dark irony. By appearing to lower the human cost of war, they may seduce us into more wars'.[432] Sarah Kreps and John Kaag, in *The Use of Unmanned Aerial Vehicles in Contemporary Conflict: A Legal and Ethical Analysis,* believe that there is complacency within many of the arguments for the use of UAS; in particular, they consider the capability of technology to ensure 'distinction', is overstated. Kreps and Kaag also discuss the hypothesis that military personnel need to be put at risk in order to satisfy moral legitimacy.[433] Ryan Tonkens, in *The Journal of Military Ethics,* argues, '…even if autonomous lethal robotic systems could be more ethical than some human soldiers in certain ways and certain situations, this is insufficient reason for

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[428] For an overview of Article 36, see International Committee of the Red Cross, 'A Guide to the Legal Review of New Weapons, Means and Methods of Warfare: Measures to Implement Article 36 of Additional Protocol I of 1977', *International Review of the Red Cross* 88, no. 864, 2006, pp.931-956.

[429] For example, for an examination of the ethics of war and the issues raised relating to UAS, see Daniel Brunstetter and Megan Braun, 'The Implications of Drones on the Just War Tradition', *Ethics and International Affairs* 25, no. 3, August 2011, pp.337-356. See also, Mary O'Connell, 'Seductive Drones: Learning from a Decade of Lethal Operations', *Journal of Law, Information and Science* 21, no. 2, 2011. O'Connell argues that, although the use of UAS is accepted by most legal experts to fall within the rules of war, the availability of UAS to commanders is resulting in the use of military force that would not otherwise occur, pp.116-139. For a well-balanced discussion on the ethics of utilising UAS, see Wing Commander Nicholas Tucker-Lowe RAF, 'RPAS and the Ethical Landscape of Contemporary Conflict', *Air Power Review* 15, no. 3 (2012), pp.1-15.

[430] See, for example, R. Sparrow, 'Killer Robots', *Journal of Applied Philosphy* 4, no. 1, 2007, pp.62-77.

[431] *ibid*.

[432] P. W. Singer, 'Robots at War: The New Battlefield', in *The Changing Character of War*, Hew Strachan and Sibyille Scheipers (eds), Oxford: Oxford University Press, 2011, p.350.

[433] Sarah Kreps and John Kaag, 'The Use of Unmanned Aerial Vehicles in Contemporay Conflicts: A Legal and Ethical Analysis', *Polity* 44, no. 2 April 2012, pp.260-285. One does not have to agree with their views, however, Kreps and Kaag give an excellent précis of the rules of distinction and proportionality, and the need for more discussion on the legal and ethical issues with UAS operations.

developing and using these machines'.[434] Although these arguments are certainly worth considering, Professor Patrick Lin and colleagues, believe such arguments have multiple flaws, arguing that, '…using robots or not makes no difference as to whether the war is in self-defence, is proportional, or is a last resort'.[435] Offering a contrary view, they believe it is likely that the development of autonomous systems will make war more ethically waged.[436] This view is gaining credence; Ronald Arkin, from the Georgia Institute of Technology, also believes that autonomous unmanned systems may eventually have the potential of performing more ethically than humans.[437]

In the same vein, Daniel Brunstetter and Megan Braun argue that the use of UAS can serve as a measure short of full-scale war, providing a more proportional response to certain security threats. They view that their use could, '…raise the threshold of last resort of large-scale military deployment by providing a way to avoid deploying troops or conducting an intensive bombing campaign while still counteracting perceived threats'.[438] Bradley Strawser, from the University of Connecticut, argues that using UAS, as long as the military action is justified in the first place, should be mandatory, if they allow for the protection of own personnel.[439] The principal of 'Military Necessity' requires '…the minimum expenditure of life and resources'.[440] This should apply equally to both sides of a conflict. Jai Galliot, from Macquarie University, strongly disagrees with Stawser; he argues that the, 'use of remote weaponry by one force, against another force without such technology, crosses some symmetry threshold making the fight intrinsically unfair and thus unjust'.[441] Galliot seems to be concerned, '…that there is indeed something powerfully disturbing and morally troubling about being killed by remote control'.[442] Is this argument logical? It may be to some, but it is a fact, that many weapons are delivered by

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[434] Ryan Tonkens, 'The Case against Robotic Warfare: A Response to Arkin', *Journal of Military Ethics* 11, no. 2, 2012, p.164. Seb Cox discusses the potential dehumanisation of war because of the use of UAS – see Cox, 'unmanned Aerial Vehicles - Cultural Issues', *op. cit*., pp.94-95.

[435] Lin, Bekey, and Abney, *op. cit.,* p.46.

[436] *ibid*., p.47.

[437] See Ronald Arkin, 'The Case for Ethical Autonomy in Unmanned Systems', *Journal of Military Ethics* 9, no. 4, 2010, pp.332-341.

[438] Brunstetter and Braun, *op. cit.,* p.339. See *ibid*., pp.342-346, for a discussion on the use of UAS and *jus ad bellum.*

[439] See Bradley Strawser, 'Moral Predators: The Duty to Employ Uninhabited Aerial Vehicles', *Journal of Military Ethics* 9, no. 4, 2010, pp.342-368. Stawser's arguments for the obligatory use of UAS are persuasive, yet, perversely, he also argues that these systems would not be ethical, if they were totally autonomous. See also, Noel Sharkey, 'Saying 'No!' To Lethal Autonomous Targeting', *Journal of Military Ethics* 9, no. 4, 2010, pp.369-383.

[440] *JSP 383*, *op.cit*., p.22, para 2.2.

[441] Jai C. Galliott, 'Viewpoint Article Closing with Completeness: The Asymmetric Drone Warfare Debate', *Journal of Military Ethics* 11, no. 4, 2012, pp.353-354.

[442] *ibid*., p.355.

‘remote control’ – the nature of warfare necessitates their use.[443] Why, therefore, should the use of UAS to deliver weapons be viewed differently? Also, militaries throughout history have strived to gain an advantage over an adversary, both in weaponry and tactics; the F-22 is an example.

While acknowledging there is an on-going academic debate, it is worth considering the argument from a military perspective. When asked his thoughts on the ethics of using ‘drones’ to kill suspected terrorists, USAF CSAF, General Norton Schwartz, rejected the whole question: ‘”Is it more ethical to engage an asset from an F-15 or an F-16 or an [unmanned] MQ-9? We have rules of engagements, so if it is a legitimate target, the manner in which we engage that target in close combat is irrelevant”’.[444] A more pertinent argument, perhaps, is put forward by Professor Markus Wagner, from the University of Miami School of Law. Wagner opines that, while autonomous systems should be able to distinguish between civilian and military targets (Distinction), because of the quantitive nature of assessment, proportionality assessment is more difficult, as it is qualitive. This, Wagner believes, makes the use of autonomous weapon systems both illegal, and ‘…highly problematic both ethically and politically’.[445]

Some arguments against the use of UAS centre on concerns about the effect they have on how states are viewed as aggressors, particularly, against religions. Michael Boyle, in *International Affairs,* believes: ‘Over time, an excessive reliance on drones will deepen the reservoirs of anti-US sentiment, [and] embolden America’s enemies…’.[446] Dr George Friedman, does not view the use of UAS as being unethical, or against the LOAC, but he does believe that their use may lead to, ‘…geographical unlimitlessness’.[447] Friedman believes:

> The enemy strategy is to draw the United States into an extended conflict that validates its narrative that the United States is permanently at war with Islam…From the U.S. point of view, unmanned aerial vehicles are the perfect weapon because they can attack the jihadist command structure without risk to ground forces. From the jihadist point of view as well, unmanned aerial vehicles are the perfect weapon because their efficacy allows the jihadists

[443] Cruise missiles and Patriot SAM systems are examples.

[444] Charles, *op. cit.*

[445] Markus Wagner, 'Taking Humans out of the Loop: Implications for International Humanitarian Law', *Journal of Law, Information and Science* 21, no. 2, 2011, p.165.

[446] Michael J. Boyle, 'The Costs and Consequences of Drone Warfare', *International Affairs* 89, no. 1, 2013, p.29.

[447] Dr George Friedman, 'Hellfire, Morality and Startegy', *Statfor Global Intelligence*, 19 February 2013, http://www.stratfor.com/weekly/hellfire-morality-and-strategy, (accessed 22 February 2013).

> to lure the United States into other countries and, with sufficient manipulation, can increase the number of innocents who are killed.[448]

It is perhaps these views that are the most pertinent when arguing the ethical nature of UAS. P. W. Singer, in *Wired for War,* uses films such as *Terminator* and *2001 a Space Odyssey* as examples of the future use of 'robots', and potential ethical dilemmas.[449] Using fictional stories to illustrate the ethics of robotics may be questionable, but Singer also states that: 'The fear amongst soldiers…[is that they]…worry war is disappearing…Lives may be saved in unmanned warfare, but war itself is becoming almost unrecognisable, something they are not all that comfortable with'.[450] Singer's findings are interesting; as already highlighted, they are in direct contrast to those of the author's. Who is correct? The jury is still out. Singer is also of the opinion that unless people are actually put in harm's way, that is, a nation is not prepared to sacrifice its own people, then the morality of wars could be undermined.[451] Although the author does not agree with this sentiment, he acknowledges that some do have this view. However, as part of a structure that can actually help prevent conflict, the use of 'robotics may actually be more ethical.

It can be argued that UAS allow greater emphasis to be placed on the distinction and proportionality process, due to their persistence, and the fact that decisions to attack can be made at relative leisure, without the stresses of actual combat.[452] Although, in theory, the technological advantages mean UAS should be better able to satisfy the principles of proportionality and discrimination, Brunstetter and Braun observe that these same advantages, aligned with the fact that the operators can be situated thousands of miles away at a computer console rather than in the line of fire, have the potential to make discriminating between combatants and non-combatants more difficult.[453] But is this, in reality, correct? Expert opinion from the ICRC gives the view that the use of UAS may improve discrimination. Fifty experts on international law, under the auspices of the Harvard Program for Humanitarian Policy and Conflict Research, have drawn up recommended rules on the use of air launched weapons in warfare; on the use of UAS, they offer the following:

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448 *ibid*.

449 See generally, Singer, *Wired for War*.

450 *ibid.,* pp.431-432.

451 Singer, *Robots at War: The New Battlefield*, p.351.

452 For example, see R. Laurie, 'After Top Gun: How Drone Strikes Impact the Law of War', *University of Pennslyvania Journal of International Law* 33, no. 3, Spring 2012, pp.689-694. As highlighted earlier, Jakob Kellenberger, President of the ICRC, views that the use of UAS may be more ethical.

453 Brunstetter and Braun, *op. cit.,* p.339. Also see, *ibid*., pp.347-352, for *jus in bello* considerations.

> Their modest size and the noise signature relative to manned aircraft may make them useful in tracking individual combatants and military vehicles without alerting them to the fact that they are being observed. Further, the ability of UAVs to loiter often allows them to monitor the target area to assess the presence of civilians at the time of attack.[454]

Perhaps it is this statement that best sums up the virtues of current UAS operations.

Summary

Kenneth Anderson and Matthew Waxman, from the Hoover Institution Task Force on National Security and Law, believe that HITL will initially be included as a fail-safe, but as improvements in technology and the pace of operations increases, the requirement will diminish.[455] They view that autonomous military systems developments will not pose a crisis for the LOAC, provided ethical and legal norms are incorporated into the design at the initial stages.[456] Armin Krishnan's extensive research concludes that there are less concerns with regards to accountability, '…than some critics of military robots believe'.[457] Anderson and Waxman sum up the future of autonomous weapon systems, such as UCAS: 'Some view these automated technology developments as a crisis for the laws of war. To the contrary, provided we start now to incorporate ethical and legal norms into weapon design, the incremental movement from automation to genuine machine autonomy can be made to serve the ends of the law on the battlefield'.[458] 'International law has never approved the defensive plea of superior order as a mandatory bar to the prosecution of war criminals'.[459] The Nuremberg Principle requires that individuals are responsible for their actions, with the LOAC requiring participants to limit collateral damage, through accurate target recognition and identification prior to engagement.[460] The question is: who is responsible for an autonomous system? Arkin and others, in *Responsibility and Lethality for Unmanned Systems: Ethical Pre-mission Responsibility Advisement,* argue, '….that by making the assignment of responsibility transparent and explicit, through the use of a

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[454] See *Commentary on the HPCR Manual on International Law Applicable to Air and Missile Warfare*, p.54, para 7.

[455] Kenneth Anderson and Mattew Waxman, 'Law and Ethics for Robot Soldiers', *Social Science Research Network* 176, 2012, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2046375, (accessed 9 August 2012), p.2.

[456] *ibid*., p.19.

[457] Krishnan, *op. cit.,* p.105.

[458] Anderson and Waxman, *op. cit.,* p.19.

[459] Wennerstrum, *op. cit.,* p.1238.

[460] The denial of the defence of superior orders has often been called the 'Nuremburg Principle', having been established at the Nuremburg Trials, post-World War II. It was not, however, a new principle; it was already recognised within many national legal systems, not least that of the German military - see Ann Tusa and John Tusa, *The Nuremberg Trial*, London: MacMillan, 1983, p.87.

responsibility adviser at all steps in the deployment of these systems, that this problem is solvable'.[461]

The current employment of UAS is generally consistent with the LOAC. Whether these systems are weaponised, or not, does not alter their legal use, it is whether the weapons are used legally.[462] The principles of the LOAC will apply equally to the use of UCAS. If these principles are adhered to, then there are no legal reasons why these autonomous systems cannot be utilised in warfare. The ethics of whether to use UCAS should be based less on current discussions regarding UAS, but more on whether nation-states can afford not to use systems that offer, not only a viable deterrent, but also an exceptional capability. Some nations may be less inclined to adhere to the LOAC, when faced with stark decisions on survival, or an action is initiated to achieve an aim, at all costs. As Noel Starky observes, although the future use of autonomous UAS, '…could be at the cost of sacrificing or stretching International Humanitarian Law…with other countries closing the military gap and able to use similar systems, why be disadvantaged by having a [HITL]?'[463] Ultimately, if the normal path that Western weapon systems development has taken, certainly since the end of the Cold War, is continued, with all the rigorous debate concerning ethics and the LOAC that this has entailed, the future utility of UCAS will be ensured.

[461] Ronald Arkin, Alan Wagner, and Brittany Duncan, 'Responsibility and Lethality of Unmanned Systems: Ethical Pre-Mission Responsibility Advisement, Georgia: Georgia Institute of Technology, 2009, https://smartech.gatech.edu/bitstream/handle/1853/31463/09-01.pdf?sequence=1, (accessed 18 January 2013, p.1.

[462] See Laurie, *op. cit.,* p.687.

[463] Noel Sharkey, 'Automating Warfare: Lessons Learned from the Drones', *Journal of Law, Information and Science* 21, no. 2, 2011, pp.153-154.

Chapter 4: The Role of Air and Space Power, and Control of the Air

'….the only security upon which sound military principles will rely is that you should be master of your own air'

Winston Churchill [464]

This chapter gives an overview of the role of air and space power, before concentrating on the principle enabling requirements and uncertainties in developing systems that can gain control of the air, in the air-to-air environment. In order to understand the possible future roles of UCAS, it is necessary to recognise the role that both air and space power plays in modern warfare. Air power was seen as NATO's most valuable asset by many during the Cold War.[465] The British definition of air power, which is reflected in UK military Joint Doctrine publications, was, until recently: 'The ability to project military force in air or space by or from a platform or missile operating above the surface of the earth. Air platforms are defined as any aircraft, helicopter or unmanned air vehicle'.[466] This definition did not include space assets. Space, along with cyber-warfare, are now both significant components of air power. The description in the 4th edition of *AP 3000: British Air and Space Power Doctrine* defines air and space power as: 'The ability to project power from the air and space to influence the behaviour of people or the course of events'.[467] Rightly, space is now regarded as a crucial domain, in addition to land, sea and air. *AP 3000* emphasises its importance:

> …[After] the spectacular success of the American-led coalition in the 1991 Gulf War… China identified the West's space capability as both its battle-winning advantage and potential point of failure, and began to invest strategically in space as a result…Over ninety percent of current United Kingdom military procurement projects rely to a greater or lesser extent on space; the Position, Navigation and Timing (PNT) function provided by [GPS], for example, supports key elements of all military operations and an increasing number of commercial activities.[468]

Space power should not be viewed as a standalone tenet of military doctrine; rather, it is an intricate part of air, land, and sea power. When viewed in this light, the components of space power that enable control of the air can be summed up as the assets that help facilitate those parts of warfare that allow for the critical enablers of Command, Control,

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[464] Richard M. Langworth (ed), *Churchill by Himself: The Definitive Collection of Quotations*, New York: Public Affairs, 2008, p.205.

[465] See AVM A. J. C. Bagnall, 'The UK's Air Defence Force', *RUSI Journal* 139, no. 5, October 1994, p.45.

[466] Director of Defence Studies (RAF), *AP 3000: British Air Power Doctrine,* 3rd Edition, Norwich: Her Majesty's Stationery Office, 1999, Chap 2, p.1.

[467] Centre for Air Power Studies, *AP 3000: British Air and Space Power Doctrine,* 4th Edition, Norwich: Her Majestry's Stationery Office, 2009, p.7.

[468] *ibid*., p.19.

Communications, Computers, Intelligence, Surveillance, Targeting, Acquisition and Reconnaissance (C4ISTAR), and spaced-based navigation systems, which are fundamental to the accurate delivery of information and many weapon systems, as well as cyber-warfare.[469]

Three types of air campaigns have traditionally been utilised within air power doctrine: counter-air, anti-surface force, and strategic air offensive.[470] Although all three of these campaigns may have to be prosecuted simultaneously, experience has shown that, when facing an adversary with potent air power, priority has to be given to achieving the required level of control of the air, that is, the counter-air campaign. The RAF now advocates that there are four fundamental air power roles (including space): control of the air, air mobility, attack, and intelligence and situational awareness.[471] Within air power roles, control of the air has primacy. The RAF's current *British Air and Space Power Doctrine* emphasises the importance of counter-air, stating: 'Control of the air is the *primus inter pares* of the four air power roles. It has doctrinal primacy because it enables freedom of manoeuvre in all of the military domains: air, land and sea'.[472] The following succinctly captures the essence of its significance:

> .…control of the air is the RAF's paramount duty: not only in defence of the United Kingdom itself, but also on expeditionary operations, where control of the air guarantees the freedom of manoeuvre and action of friendly air, land and naval forces, while curtailing the activities and options open to our adversaries.[473]

Significantly, the importance of situational awareness has been acknowledged, and is now understood to be a major factor in air warfare.

For the purposes of this thesis, when the term air power is used, it encompasses the domain of space, but will not examine its strengths and weaknesses in depth. It will, however, scrutinise those aspects of space power pertinent to the employment of future UCAS.[474] RAF air power doctrine identifies the strengths of air power as height, speed, reach, ubiquity, agility and concentration.[475] However, there are inherent limitations as well as strengths - weaknesses are given as impermanence, limited payload, fragility, cost,

[469] *ibid.* p.19.

[470] *AP 3000: Air Power Doctrine*, Chap 3; p. 27.

[471] *AP 3000: British Air and Space Power Doctrine*, pp.37-38.

[472] *ibid.*, p.38.

[473] UK Ministry of Defence, 'Control of the Air,' *RAF Operational Update,* 2011, http://www.raf.mod.uk/rafoperationalupdate/opsupdate/controloftheair.cfm, (accessed 3 May 2011).

[474] For an overview of the fundamental considerations of employing air and space power, see *AP 3002 – Air and Space Warfare*, Chap 4.

[475] *Ap 3000: British Air and Space Power Doctrine,* pp.18-19.

dependency on bases, and sensitivity to weather.[476] For a simpler view of the attributes of air power, Professor Phillip Sabin believes that air and space power platforms have three basic strengths, and one weakness. Strengths are: *Perspective* – because of the height that aircraft and satellites operate at, they have the ability to see over large distances; *Speed,* and *Overflight* – the freedom to operate in three dimensions, makes it difficult to negate their effect. The one weakness is *Energy Needs.*[477] One does not have to agree with Sabin, however, these terms do capture the fundamentals. Persistence and the ability to deliver an effect will be important traits of any future air system. Although AAR is of primary importance as a force multiplier *par excellence*, and is used to enhance the capabilities of many aircraft types in almost all air power roles, no means have yet been found to re-arm, re-crew or service an aircraft in flight.[478] These limitations may be overcome, to some extent, in future systems, such as UCAS equipped with DEW.

The enduring lesson of the last 90 years is that air power does not win large-scale high-intensity conflicts on its own, although the two recent Gulf Wars have given the impression that air power achieved this.[479] While this is not true, air power has a vital role in any campaign.[480] Although these wars were indeed large-scale and of high-intensity, they were of relatively short duration. Following the 1991 Gulf War, air power was used to enforce a no-fly zone over two separate areas of Iraq, north and south. The experience of living under the threat of any Iraqi combat fixed-wing aircraft or helicopter being shot down during the period 1991 – 2003, aligned with periodic targeting of selective C2 facilities, led the Iraqi Air Force to essentially give up when faced with overwhelming force during the 2003 Gulf War. No Iraqi combat aircraft got airborne during this conflict; the Iraqi military started to bury most of its combat aircraft – a classic example of deterrence at work.[481] Although the Iraqi IADS presented a threat, at least initially, control of the air was achieved relatively

[476] *ibid.*

[477] Sabin, *op. cit*., p.160.

[478] It has long been appreciated that aircraft may become ineffective due to weapon expenditure, even if able to remain airborne for long periods. In the 1970s, the RAF and British Aerospace conducted a study into the efficacy of rearming Tornado ADV in flight, from a trapeze pallet trailed from a VC-10; it was never trialled – see Chris Gibson, *Battle Flight: RAF Air Defence Projects and Weapons since 1945*, Manchester: Hikoki Publications Ltd, 2012, p.200.

[479] See, for example, Robert A. Pape, 'The True Worth of Air Power', *Foreign Affairs* 83, no. 2, March/April 2004, pp.116-130. For a short, but excellent overview of air and spacer power, see Karl P. Mueller, 'Air Power', in *The International Studies Encyclopedia*, *vol. I*, Robert A. Denemark (ed), San Francisco, CA: Wiley-Blackwell Publishing, 2010, pp.47-65.

[480] For a view on the concept of air power, in particular, its effectiveness during the 1991 and 2003 Gulf Wars, see Forest E. Morgan, 'The Concept of Airpower: Its Emergence, Evolution, and Future', in *The Chinese Air Force: Evolving Concepts, Roles, and Capabilities,* Richard P. Hallion, Roger Cliff, and Phillip C. Saunders, (eds), Washington, DC: National Defense University Press, 2012, pp.1-31.

[481] Martin van Creveld, *The Age of Airpower*, New York: Public Affairs, 2011, p.333. See also, Gp Capt R. Powell RAF and Gp Capt R. Birch RAF (Retd), 'Op Telic', in *25 Years of Air Defence: Tornado F3,* Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.147-150.

quickly. This reinforced the utility of air power, allowing coalition air forces to operate with confidence; it forcefully demonstrated the utility of contemporary air power. Most recently, the 2011 Libya campaign conducted by a UK/France/US led coalition demonstrated that air and space power alone can, in certain scenarios, achieve all the required objectives.[482] The Free Libya Forces were all ground-based, and were a disparate group of peoples/tribes, who would have been very unlikely to succeed against Libyan Government forces, without coalition air power effectively targeting and negating the air defence system, C2 nodes, and pertinent military and government infrastructures. Air power has other attributes of course; it can be utlilised not only to effect the destruction of an adversary's centre of gravity, for example, but also to help prevent conflict in the first place.[483] Perhaps air power's capability to concentrate force in time and space is its greatest asset, although this is only for limited periods, unless massive assets are available.[484]

Historical examples help give a perception of the relative strengths and weaknesses of air power. Alexander Seversky argued that the rescue of the British Army from Dunkirk was only possible because the RAF had control of the air. This control permitted the Royal Navy (RN) to evacuate over 300,000 troops.[485] Had the Luftwaffe owned the skies, the British evacuation operation would not have been anywhere near as successful as it was.[486] During the 1982 Falklands War the Argentineans started from a position of considerable strength relative to the British Task Force, yet their apparent lack of any coherent air strategy meant that they quickly lost air superiority over the Falkland Islands. This was despite the British Forces having no dedicated all-weather air defence aircraft. The RN's Sea Harrier and the RAF's Harrier were very definitely limited to short range, visual and clear weather intercepts, owing to a limited capability of the airborne radar in the

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482 See Anrig, *op. cit.,* pp.89-109.

483 For a discussion of the attributes of air power in conflict prevention, see Group Captain Clive Blount RAF, 'Prevention Is Better Than Cure: What Is the Utility of Air Power in Conflict Prevention?', *Air Power Review* 13, no. 3, 2010, pp.85-94.

484 See Andrew Vallance, *The Air Weapon: Doctrines Strategy and Operational Art*, Basingstoke: Palgrave Macmillon, 1996, p.27.

485 Alexander de Seversky, *Victory through Air Power*, New York: Simon and Schuster, 1942, p.30. Seversky was a fanatical advocate of air power; his views on air power, particularly during WW II, caused a sensation, with his book *Victory through Air Power,* selling 5 million copies and being made into a film by Walt Disney. Sevresky was an enigmatic character, himself an accomplished fighter pilot, having become an ace with the Russian Naval Air Force, before immigrating to the US, and becoming an adviser and consulting engineer to the War Department – see *ibid*, p.159. Seversky views offered many air power fundamentals which remain extant, for example, the importance of gaining air superiority – see *ibid*, p.157. Phillip Meilinger believes, however, that Severskey was more a proselytiser (someone whom converts people to a way of thinking), than a prophet; his ideas on air power were not original; also, his views on the future dominance of air power, and the subservient roles of armies and navies were somewhat simplistic – see Phillip S. Meilinger, 'Proselytiser and Prophet: Alexander P. De Seversky and American Airpower', *Journal of Strategic Studies* 18, no. 1, 1995, pp.7-35.

486 J. Gooch (ed), *Air Power: Theory and Practice*, London: Frank Cass Publishers, 1995, p.15.

Sea Harrier, and in the case of the RAF's Harrier, no radar at all.[487] If the British Task Force had possessed dedicated AEW, and if any of the RN's aircraft carriers had been capable of operating the F-4 Phantom - at that time the RAF's primary air defence fighter - equipped with a radar and weapons with the ability to find, track and engage aircraft at all heights and in all weather, at significant ranges from the Task Fleet, British naval losses would probably have been far fewer.[488] Major James Thigepen, USMC, emphasises the lack of AEW assets, which the F-4 Phantom was capable of providing, viewing that, '…the British were lucky that their static defence in-depth worked given their inability to see, shape, and manoeuvre in the skies over the Falklands'.[489]

Although air power does have limitations, thanks to its speed and reach, it can counter threats across a far wider geographical area than is generally possible with surface systems. These two tenets make air power unique and are perhaps air power's greatest strengths; it can be deployed rapidly to provide visible and timely support or to act as a deterrent, particularly over great distances. Growing effectiveness has tended progressively to widen air power applications. For example, for closer threats, it can also be used rapidly, direct from its peacetime bases. The Kosovo conflict in 1999 is an example of this, when RAF Tornado GR-1 strike aircraft flew night sorties from their bases in Germany.[490] Nonetheless, the full utility of air power can, at times, be limited by political constraints. Both Gulf Wars were examples of how politicians and commanders were intensely aware that a large loss of life of Iraqi civilians and coalition troops would be publicly unacceptable; great effort was made to avoid collateral damage to structures, wherever possible. Where poor targeting has resulted in civilian deaths, as in Kosovo during Operation Allied Force in 1999, public perception is that air power was used indiscriminately. In fact, the targeting error rate was 1%, and although it led to approximately 500 civilian deaths, it was considerably better than any previous operation.[491] However, there is a trend amongst the democratic international community to not countenance casualties amongst civilians in conflicts not directly affecting their own country, or national interests. Large inter-state conflicts, risking global escalation, may alter this antipathy to accepting casualties and collateral damage.

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[487] For an account of the rapid modifications made to the RAF Harriers in order to make them both carrier and air-to-air capable, see Ethell and Price, *op. cit.,* pp.21-23.

[488] The AWG-10 Pulse-Doppler radar, which RAF F-4s possessed, was introduced into the F-4 to allow for a look-down, shoot-down capability - see, Francis K. Mason, *Phantom*, Cambridge: Patrick Stephens Ltd, 1984, pp.83-84.

[489] See Major James E. Thigpen USMC, *Marine Air-Ground Task Force Air Defense and Maneuver Warfare,*1989, http://www.globalsecurity.org/military/library/report/1989/TJ.htm, (accessed 19 July 2012).

[490] UK Minstry of Defence, *Kosovo: Lessons from the Crisis,* London: The Stationery Office, 2000, Chap 7.28, p.40.

[491] *ibid,* Chap 7.11, p.36.

While air power has been employed for strategic effect since its inception, the differences now, as opposed to operations as recently as the Falkland's War, are the accuracy of delivery systems, aligned with the capabilities of ISTAR assets, enabling these systems to be used to maximum effectiveness, while using fewer assets. All forms of modern military power depend on base support if they are to operate at their maximum sortie rate. Armies in the field need depots to support them and navies need harbour facilities. However, air power is often more dependent on its bases than are either land or sea power. If this base support is vulnerable to attack, then base-dependency can be a source of potential weakness.[492] This axiom can also apply to a carrier task force, if it cannot adequately protect itself, or it does not have the option to remain outside the range of adversary threat systems.

An air force's mission is to deliver air power in the most effective manner possible to meet a nation's security and defence requirements. In order to achieve this, a balanced force must be maintained, one capable of all air power roles and able to meet the requirements for high and low-intensity conflict, if mandated to do so. Although there has been an increasing requirement to deploy and sustain forces for expeditionary warfare, it is necessary for the UK and other members of NATO to retain the capability to meet the requirements of NATO Article 5, which means that an attack on any NATO country is considered an attack against all members and will be met by joint responsive action.[493] The UK has provided a level of air power support in the Iraq - (having left) - and Afghanistan theatres of operations, second only to the US. Although Man-Portable Air Defence Systems pose a threat, importantly, no air threat exists in either country; the RAF's role has currently been biased towards the COIN threat, concentrating on Close Air Support and gathering intelligence through its ISTAR assets. This threat is very much 'today's' threat. The threat faced by the UN alliance during the Libyan conflict in 2011 was towards the lower end of a competent IADS. The lack of competent C2 and the actual poor density of SAM, meant that, although still a threat, the Libyan defences were made redundant relatively quickly, for no coalition losses. This IADS was made completely ineffective relatively quickly, from bases that were largely land centric, within 200 – 500 nm of the threat targets.[494] In certain future conflict scenarios it is extremely likely that a UK/US, NATO or other alliance, will have to contend with significantly more capable IADS,

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[492] See *AP 3000: British Air and Space Power Doctrine*, p.18. This states that gaining host nation support has rarely been a problem. However, this can never be guaranteed; the 2003 Gulf War, where Turkey did not support coalition ground operations, is an example – see Cameron S. Brown, 'Turkey in the Gulf Wars of 1991 and 2003', *Turkish Studies* 8, no. 1, 2007, pp.97-101.

[493] North Atlantic Treaty Organization, *NATO Handbook*, Brussels: NATO, Public Diplomacy Division, 2006, p.372.

[494] The Libyan IADS could not realistically be described as 'integrated. See generally, Anrig, *op. cit*., pp.89-109.

with states intent on denying access to safe bases and sea operating areas. The USAF acknowledges that since the fall of the Soviet Union, while it has had overwhelming dominance in air power capabilities, it faces new challenges, not least from China, which will test its current force structures.[495]

The US's approach to its air power capabilities is closely aligned to the UK's, but does emphasis other areas. A recent strategy study by the Air Force Research Institute, *Air Force Strategy Study 2020 – 2030*, sought to analyse US interests, including economic, demographic, and technological trends, defence scenarios, and the USAF's capabilities to meet future strategic challenges. Its findings recommend that the USAF focus on five critical capabilities out to 2030: power protection; freedom of action in air, space, and cyberspace; global situational awareness; air diplomacy, and military support to civil authorities. The study emphasises the importance of integrating the three domains of air, space, and cyber.[496] In recognising that the two mediums of cyberspace and the electromagnetic spectrum (EMS) are converging, the US is attempting to combine cyber, EW and computer network operations (CNO) into what is termed 'the third dimension'.[497]

Air power, although crucial, is just one role making up the matrix required to target an adversary's 'centre of gravity' – that point where the enemy is most vulnerable and the point where an attack will have the best chance of being decisive.[498] Colonel John Warden USAF (Retd), in *The Air Campaign,* articulates very effectively on the centre of gravity: 'Every level of warfare has a center, or centers, of gravity. If several centers of gravity are involved, force must be applied to all if the object is to be moved'.[499] Clausewitz was perhaps one of the originators of the 'Centre of Gravity' doctrine; however, Colonel John Boyd, in *Patterns of Conflict* argues that:

> Clausewitz incorrectly stated: "a center of gravity is always found where the mass is concentrated most densely"…then argued that this is the place where the blows must be aimed and where the decision should be reached. He failed to develop [the] idea of

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[495] See Zalmay Khalilzad, David Ochmanek, and Jeremy Shapiro, 'United States Air and Space Power in the 21st Century', in *Forces for What? Geopolitical Context and Air Force Capabilities*, Zalmay Khalilzad and Jeremy Shapiro (eds), Santa Monica, CA: RAND Corporation, 2002, pp.35-43.

[496] General John A. Shaud USAF (Retd) and Adam B. Lowther, 'An Air Force Strategic Vison for 2020 - 2030', *Strategic Studies Quarterly* 5, no. 1, 2011, p.8.

[497] The US army, for example, emphasises this 'third dimension', see - US Army Capabilities Integration Center, 'The United States Army's Cyberspace Operations Concept Capability Plan: 2016 - 2028', in *TRADOC Pamplet 525-7-8,* Fort Monroe, VA: Department of the Army, 2010, http://www.tradoc.army.mil/tpubs/pams/tp525-7-8.pdf, (accessed 19 April 2011), pp.i-ii.

[498] *AP 3002 – Air and Space Warfare,* Chap 3, p.13.

[499] John A. Warden III, *The Air Campaign: Planning for Combat*, San Jose: toExcel Press, 2000, p.7.

> generating many non-cooperative centers of gravity by striking at those vulnerable, yet critical, tendons, connection, and activities that permit a larger system…to exist.[500]

Although air power may be capable of achieving the strategic aim, the capability to undertake such missions is not easily gained, or maintained. Ultimately, however, the author believes that the capabilities demanded of high-intensity conflict remain paramount; the preservation of such capabilities will underpin the ability to field forces structured adequately for low-intensity conflict and Peace Support Operations. Air power can provide coercive or retaliatory actions to discourage regimes from unacceptable actions, adding to nations' deterrence capabilities. Once gone, this ability could take considerable efforts to regain. In the meantime, a valuable strategic influencing tool is also lost. In particular, the demands of control of the air require special consideration.

Control of the Air

'The struggle for air superiority is part and parcel of all air operations against a first-class enemy' [501]

Already established, combat air power requires to be generated from close, secure bases, both land- and sea-based. Within combat air structures there are a number of key enablers to achieving airspace dominance. Before any attempt to hypothesise on future counter-air requirements, it is important that these critical enablers be understood. These enablers are BVR air-to-air combat, gaining situational awareness of the battlespace, stealth technology, NEC, AAR, and EW; all are of prime importance.[502] Other components consist of the sensors required, sea-, land- and space-based assets and, if defending one's own homeland or sea-based forces, an IADS. A system that gives the first detect, first engagement, first kill capability is vital. Gaining this capability requires an understanding of AAM and AAS P_k principles, and how these affect the air battle.

During the initial stages of World War I, military aviation was mainly concerned with the role of reconnaissance; however, the potential for bombing and air-to-air combat soon became apparent. 1915 saw the development of fighter aviation, including mechanical interrupter gears, which enabled guns to fire through the arc of spinning propellers. By 1916, control of the air emerged as the crucial issue in the Germans' Verdun offensive and the British

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[500] John Boyd, 'John Boyd Compendium', *Defense and the National Interest*, 2007, http://dnipogo.org/john-r-boyd/, (accessed 12 August 2012), *Patterns of Conflict: Historical Pattern – Carl Von Clausewitz-"On War"-1832,* slide 41.

[501] Wing Commander J. C. Slessor RAF, *Air Power and Armies*, London: Oxford University Press, 1936, p.10. Slessor later became the RAF Chief of the Air Staff.

[502] For a view on the requirements of a modern Air Superiority fighter, see Lt Col Devin L. Cate USAF, *op. cit*., pp.11-15.

Somme counteroffensive. A revolution was beginning; control of the air was increasingly viewed by air and ground commanders as a means of allowing the observation and the attack of enemy ground forces. The development of fighter aviation to counter these missions was a direct result of their increasing importance. [503] By 1917 it was becoming evident that poor reconnaissance of an enemy's disposition could cost all the gains of a successful previous attack.[504] The disparate requirements of the British Army and the Royal Navy, both with independent air services, led to the Smuts Report, which recommended the formation of a single air service, combining the Royal Flying Corp (RFC) and the Royal Naval Air Service (RNAS).[505] The RFC was formed at the start of World War I, with Lieutenant General Sir David Henderson as its first commander.[506] The 1st April 1918 saw the establishment of the RAF by amalgamating the RFC and the RNAS.[507] Hugh Trenchard was appointed General Officer commanding the RAF on 13 May 1918.[508] Air power had come of age and was now seen as an integral part of military operations, with control of the air acknowledged as being an essential element of any campaign.

Some air power strategists have stated that gaining control of the air is so important it might bring victory in itself. General Guilio Douhet, the Italian air power theorist, stated in his seminal work *The Command of the Air*: '…to have command of the air is to have victory'.[509] General Erwin Rommel, speaking after the failed North African campaign, stated: 'Anyone who has to fight, even with the most modern weapons, against an enemy in complete control of the air, fights like a savage against a modern European army'.[510] Whatever the desired degree of control of the air required, against an adversary with a capable IADS, or

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[503] John H. Morrow, *The Great War in the Air: Military Aviation from 1909 to 1921*, Washington, DC: Smithsonian Institution Press, 1993, p.85.

[504] *ibid.*

[505] The Smuts Report recommended, *inter alia*, that an air ministry be instigated as soon as possible, and for the amalgamation of the RNAS and the RFC into a new air service – see General Jan Cristain Smuts, 'Committee on Air Defence and Home Defence against Air Raids - Second Report', in *Formation of the RAF and Air Policy Committee: General Smuts' Report to the War Cabinet, 1917: MFC/ 76/1/2 Trenchard Papers,* RAF Museum, Hendon: Department of Archives & Aviation Records, 1917, paras 10(1) and 10(3).

[506] Henderson was to prove instrumental in the formation of the RAF. Henderson became Director-General of Military Aeronautics in February 1916. In 1917, he worked with General Jan Christian Smuts on the Smut's Report to the War Cabinet, which recommended the formation of a separate air service – see John Bourne, *Sir David Henderson,* University of Birmingham, Centre for First World War Studies, http://www.birmingham.ac.uk/research/activity/warstudies/research/projects/lionsdonkeys/d.aspx, (accessed 9 March 2013).

[507] This was instigated by the UK Parliament's 'Air Force' Bill, passed on 29 November, 1917 – see, Royal Air Force Organisation, 'The Evolution of an Air Ministry', http://www.rafweb.org/Air_Boards.htm, (accessed 16 May 2012). Although it was deemed crucial that the RAF be formed as soon as possible after this Bill, the complexity of issues such as pay, pensions, and a Code of Discipline, meant a delay until 1 April 1918 – see Smuts, *op. cit.,* Para 5.

[508] The Secretary - Air Ministry, *Trenchard Papers: MFC 76/1/28 - Letter to Trenchard, 13 May 1918*, RAF Museum, Hendon: Department of Archives & Aviation Records.

[509] Giulio Douhet, *The Command of the Air*, Dehradun: Natraj Publishers, 2003, p.26.

[510] Ronald Lewin, *Rommel: As a Military Commander*, New York: Ballatine Books, 1972, p.275.

the ability to project air power, air superiority, let alone air supremacy may be very difficult to achieve. However, unless control of the air is achieved, the full utility of a nation's own military force may not be achievable.

Richard Hallion, in *Control of the Air: The Enduring Requirement*, articulates very effectively the importance of control of the air. Going further than most academics and military theorists, he delineates control of the air into three spectrums, within the field of warfare as a whole: the freedom of initiative, the freedom to operate, and the freedom to manoeuvre, which he describes as:

> Freedom of initiative refers to the ability of the air-dominant adversary to control the…nature of the conflict: to hold an adversary…behind-the-decision-making-curve. Freedom to operate is characterized by the ability of military forces to conduct all of their functions…without fear of that foe attacking them in any meaningful or significant way…Freedom to maneuver embraces the ability for joint military forces to operate unhindered on land, [air] and sea within an area of operations...[511]

Hallion emphasises that when fighting a near-peer or peer adversary, the battle for control of the air takes on even more critical importance, and at the same time, will become increasingly difficult to achieve. Fighting under these circumstances, a force's own survival is of crucial importance, before any other mission objectives are achieved. Counter-air assets are required to defend as well as attack, limiting their ability to gain advantage over an adversary.[512] Warden also emphasises this aspect and the importance of maintaining reserve forces.[513] Indeed, an air-to-air battle can arise that consumes all air assets just in order not to lose the battle before anything else is achieved. Having the capability to achieve air supremacy, and even localised air superiority is crucial in this scenario; if not, all other forces are severely constrained, if not made impotent. Having mere parity, or even superiority, may not be enough, when confronted with an adversary that utilises its military forces across all fronts. Air supremacy would seem to be the only option – is this possible to achieve against a peer or near-peer adversary? A peer competitor is defined by the US DoD, as, '…in the national sense, is any nation whose capabilities are such that in a supreme test of wills with the [US], the outcome is uncertain.'[514] Near-peer adversaries are less able, but would have the capabilities to attack satellites with DEW, and also conduct CNO, for example.[515] Examined in Chapter Six, are the capabilities of

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[511] Richard P. Hallion, *Control of the Air: The Enduring Requirement,* Bolling AFB, Washington, DC: Air Force History and Museums Program, 1999. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1004&context=usafresearch, (accessed 9 September 2009), pp.5-6.

[512] *ibid*., p.4.

[513] For a viewpoint on the importance of reserves, see Warden, Chap 1; pp.16-20.

[514] See Dr Craig Fields and Richard Haver, *Challenges to Military Operations in Support of U.S. Interests,* Washington, DC: US Department of Defense: Defense Science Board, 2008, http://www.acq.osd.mil/dsb/reports/ADA491393.pdf, (accessed 18 May 2009), p.6.

[515] *ibid.*, p.78.

China to conduct counter-air operations in future warfare. If the threat from China were such that it was a peer adversary, the required systems to counter or deter it would be need to be revolutionary.

The Counter-Air Campaign

Knowledge of the components of a counter-air campaign is fundamental to an understanding of the requirements for future UCAS. Although definitions of counter-air have varied, the principles that encompass the full range of counter-air tasks have remain constant. The combat air component of the counter-air campaign consists of OCA and DCA operations. OCA is a combination of SEAD, EW, air-to-surface and, not least air-to-air missions. Equally important, but at times completely independent of OCA operations, are DCA operations, which comprise all measures designed to neutralise or reduce the effectiveness of hostile air action, normally over own territory, or when particularly high value asset requires protection, such as a navy task group, or military command structures.[516] These counter-air operations can be prosecuted in a number of ways; firstly, by defensive actions to minimise the risk of air attack and the damage which may be sustained by friendly forces and facilities; secondly, by seeking out the critical nodes of an IADS, and enemy aircraft, before or after they have attacked their targets, to inflict maximum attrition - although it is always preferable to destroy these aircraft before they reach their target; finally, as part of an OCA campaign, by mounting air operations in depth, and if necessary, over potentially hostile territory, to seize and retain control of airspace. Ultimately, OCA operations are mounted to destroy, disrupt or limit enemy air power as close to its source as possible. Deciding where the priority lies between the various types of counter-air operations will depend partly on friendly vulnerabilities and partly on the nature of the threat. The RAF's *AP 3002 – Air Warfare* describes counter-air as:

> Counter-air involves those operations conducted to achieve a desired degree of control of the air, through the destruction, degradation or disruption of enemy aircraft and missiles, in order to allow all friendly forces greater freedom of action whilst minimizing their vulnerability to detection and attack…Counter-air operations include all actions, taken by any component, to gain and maintain the required degree of control of the air. Effective counter-air requires timely collection, processing, analysis, production and dissemination of reliable and accurate intelligence. Real-and/or near-real-time information from air, surface and space based sensors is used to provide warning, SA, targeting and combat assessment...[517]

Most air campaigns will invariably contain some offensive operations. The success of OCA operations against an enemy with a credible air threat requires dedicated SEAD, fighter sweeps, and air-to-surface capabilities. SEAD operations are an integral part of achieving

[516] See *AP 3000: British Air and Space Power Doctrine,* p.39. Active and passive air defence are also components of counter-air operations. These comprise, *inter alia*, layered defence-in-depth assets, such as IADS, and early warning systems and stealth technologies.

[517] *AP 3002 – Air and Space Warfare*, Chap 7, p.3.

control of the air – they neutralise, destroy, or temporarily degrade enemy air defence systems in a specific area by physical attack and/or EW. The US DoD describes SEAD missions as, '…[involving] the electromagnetic spectrum to neutralize, degrade, disrupt, delay, or destroy elements of an enemy's IADS…SEAD targets include radars for early warning/ground-controlled intercept, acquisition radars, SAM, and anti-aircraft artillery'.[518] SEAD capabilities have become increasingly important, as countries with a capable IADS pose a significant threat to all combat and support aircraft.

Within an OCA formation of aircraft, fighter sweeps, also referred to as fighter screens by US forces, are used to seek out and destroy enemy aircraft in an allocated area of operations. Fighter sweep is generally broken down into two groups, area and route sweep. An area sweep is used to establish control of the air in a given area. It may be used in isolation from other air assets, or it may be used indirectly to support an attack force by decoying or destroying enemy aircraft that pose a direct threat to the attack force. This form of sweep may be some hours ahead of the main attacking package.[519] A route sweep is used in direct support of an attack force, clearing the planned route of enemy aircraft that may pose a threat to the attack force. It is usually used in conjunction with escort, which involves the mission of aircraft to protect other aircraft. Escort fighters present a direct last line of defence to an adversary's fighter aircraft.[520]

The counter-air response is likely to be shaped by the nature of the overall military campaign. Fundamentally, the counter-air campaign has three elements: first, the means to detect, identify and track potential targets and to direct weapons systems; second, a command, control, communications and information infrastructure to link the weapons and detection systems; finally, weapons systems to destroy adversary air systems, and more frequently, the requirement to counter cyber and space assets.[521] The axiom of 'know your enemy' still holds. Without knowledge of an adversary's capabilities and disposition, it is likely that a nation's combat assets will not be used to best effect. This knowledge is not easily gained. A comprehensive mechanism of information gathering is required. This will include national intelligence agencies and academic institutions that are able to give a holistic view of nations' capabilities and intent. An adversary's intent is just as important as its capabilities. Although the two may go hand-in-hand, it is important to have an

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[518] US Air Force Doctrine Center, *Electronic Warfare: Air Force Doctrine Document 2-5.1,* Washington, DC.: US Department of Defense, 2002, p.8.

[519] See Shaw, *opt. cit*., pp.316-345.

[520] *AP 3002 - Air and Space Warfare*, Chap 7, pp.5-6. Most modern fighter/bombers are capable of self-escort.

[521] *ibid.,* Chap 7, p.9.

understanding of what is behind an arms build-up; for example, is it as part of an overall deterrence strategy, or is it part of a plan to launch an offensive to gain control of shipping access points, or to force another country to capitulate to demands.[522] Information, which is part of the situational awareness chain, is critical to the counter-air campaign. Many of the necessary assets described are part of this chain; without this information, all the impressive military hardware available could be made almost useless.

The ability to conduct the full gamut of counter-air operations requires a wide range of skill-sets, from all personnel involved. Fighter aircrews need to be able to digest information quickly, react accordingly, assess, and then start the process again. Much of this is done BVR, however, the classic air-to-air combat arena is usually perceived as being a Battle of Britain type scenario, or from the 1986 film 'Top Gun', where kills where achieved by getting in close to the enemy - that is seeing him, and manoeuvring hard to achieve a kill, or prevent being killed.[523] Whether there will be a call for this type of combat in 2040 demands examination. Leaving this argument aside for the moment, air-to-air combat is one of the most cognitively and physically demanding tasks fighter crews engage in, particularly in the visual, close in, arena.[524] It demands that a pilot skillfully manipulates the control column and throttles - referred to in modern fighters as Hands on Throttle and Stick (HOTAS) - to control radar and weapon systems, while keeping track of, and responding to, opponents and friendly aircraft manoeuvres in a rapidly changing three-dimensional environment.[525] The pilot must do this while often flying the aircraft at the very limits of its turning performance, and straining to prevent loss of consciousness resulting from extreme g-forces. It is difficult to quantify all the skill sets required. John Stillion's PhD thesis discusses the issues facing the training of fighter crews, viewing: '…air-to-air combat skills are among the most perishable fighter crew combat skills…'.[526] The US experience during the Vietnam War, for example, viewed counter-air (MIGCAP) missions as the most demanding, requiring, '…an intimate knowledge of the weapon system, a thorough

[522] For an explanation of the function and importance of intelligence, see *ibid.,* Chap 2, p.3 and Chap 6, p.3.

[523] For an overview of air combat, from WW I to the modern era (circa 1985), and the requirement to get close to an adversary, see Shaw, *op. cit*., pp.1-31.

[524] For an analysis of the skill-set required of fighter pilots, see Peter deLeon, *The Peacetime Evaluation of the Pilot Skill Factor in Air-to-Air Combat,* Santa Monica, CA: RAND Corporation, 1977, Chap V, pp.40-47.

[525] For a view of the role of a modern fighter pilot, see Flt Lt John Cockroft RAF, 'F3 Driver: Pilot', in *25 Years of Air Defence: Tornado F3,* Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, pp.94-95.

[526] See John Stillion, *Blunding the Talons: The Impact of Peace Operations Deployments on USAF Fighter Crew Combat Skills,* PhD Thesis, Santa Monica, CA: RAND Graduate School, 1999, p.80.

knowledge of high performance characteristics and capabilities of the aircraft, and extremely close coordination between cockpits and flight members'.[527]

Summary

In 1918 it was appreciated by the British military that 'air supremacy', would become as important as 'sea supremacy'.[528] Since then, control of the air has become a fundamental prerequisite for any planned military endeavour in the 21st Century. Unless control of the air is achieved, all other types of air, surface, and sub-surface operations become increasingly difficult, and often impossible, to sustain. Ground and naval surface forces can and have made major contributions to the counter-air campaign. Their contribution can be even greater if they are thoroughly integrated into the mission.[529] Once control of the air is obtained, the potential of air power can be fully exploited, allowing effective combined attacks to be conducted. The more formidable the opposing air power, the more important this task becomes. Achieving the desired degree of control of the air will continue to be an essential element of any military campaign.

Implementing UAS to conduct ISTAR and air-to-surface strike missions has been achieved, at least in non-contested airspace, while the utility of air-to-air UCAS has barely entered into the academic sphere of interest, let alone military procurement requirements.[530] Whatever systems are used, there are some maxims that will drive the key enablers required to gain control of the air. What happens if some of the key enablers fail? Will there be access to secure air bases or aircraft carriers close enough to the threat? Will stealth technology work as publicised? Will BVR AAM work? Perhaps most importantly, can the required advantage be gained if outnumbered and outmanoeuvred?[531] Analysis from the Center for Strategic and Budgetary Assessment questions, '…whether the USAF can depend on any of these key enablers of air power in the future primarily due to growing

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[527] USAF Tactical Fighter Weapons Center, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis – Part 1: Tactics, Command & Control and Training*, Nellis Air Force Base, NV: 1974, p.38. This report was obtained by the author from the USAF Historical Research Agency.

[528] Smuts, *op. cit.,* para 11.

[529] David E. Johnson, *Learning Large Lessons: The Evolving Roles of Ground Power and Air Power in the Post-Cold War Era,* Santa Monica, CA: RAND Corporation, 2007, p.107.

[530] Recent and current operations in Iraqi and Afghanistan are examples.

[531] See generally, John Stillion and Scott Perdue, 'RAND: Project Air Force - Air Combat Past, Present and Future', 2008, http://www.docstoc.com/docs/42891479/Air-Combat-Past-Present-and-Future#, (accessed 28 October 2011),

challenges associated with anti-access and area-denial (A2/AD) strategies and enabling capabilities'.[532]

Minimal vulnerability to attack, again, sometimes aided by stealth and superior BVR-systems, are the current requirements to engage and destroy adversary fighters, and maintain an advantage. Putting all of this into context enables a clear understanding of the foundation that underpins the future counter-air systems that will be essential to successfully dominating the battlespace. The PRC is an example of a nation approaching peer adversary status. Although it is highly unlikely that Iran will even be a near-peer adversary in 2040, Iran will certainly seek to develop a highly sophisticated IADS.[533] Both China and Iran will likely utilise A2/AD doctrine, presenting a challenging situation for the US and its allies – this is examined in Chapter Six.

Components of the Counter-Air Campaign

An air campaign will begin with intricate planning, normally as part of joint operations. The many components required to mount an air campaign will depend on the complexity of the task, but will normally consist of a number of essential branches. Gaining control of the air comprises many of these branches. Operating bases, stealth technology, weapon systems, C2, NEC, the sensors on counter-air aircraft, AAR, EW, and ground-based assets, such as IADS, are some of the component parts.[534] All of these capabilities aid, both directly and indirectly, situational awareness. When planning any OCA mission, a thorough understanding of the assets available, and their capabilities, is essential. It is inconceivable that any offensive force will not have all the assets required. All major Western powers place great emphasis on OCA training; it is in this sort of scenario in which counter-air assets are tested to their limits.[535] While this type of training is essential for high-intensity conflicts, it builds on capabilities that are suitable in low-intensity conflicts as well. While OCA training has largely been a Western preserve since the end of the Cold

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[532] Mark Gunzinger and Chris Dougherty, *Outside-In: Operating from Range to Defeat Iran's Anti-Access and Area-Denial Threats,* Center of Strategic Budgetary Assessment, 2012, http://www.csbaonline.org/wp-content/uploads/2012/01/CSBA_SWA_FNL-WEB.pdf, (accessed 6 March 2012), p.17.

[533] Iran has augmented its largely obsolescent modern short-range air defence systems, acquiring Russian SA-15 Gauntlet, and SA-22 Greyhound SAM. Russia rejected the idea of deliveries of modern S-300PMU1 (SA-20 Gargoyle) long-range SAM in 2010, although a future shift in Russian policy represents a potential risk - see Anthony H. Cordesman and Alexander Wilner, *U.S. and Iranian Strategic Competition: The Conventional and Asymmetric Dimensions,* Washington, DC: Center for Strategic & International Studies, 2012, pp.40-41.

[534] For an explanation on how Joint Air Operations are planned, and for the specialist branches required, including, intelligence, EW, cyber-space ops, weapon systems, air and missile defence planning, information ops, command, control and communications - see US Department of Defense, *Joint Publication 3-30, Command and Control of Joint Air Operations,* 2010, Chap III-4, Figure: 111-3, p.55.

[535] Exercise Red Flag, held in the US, is an exemplar of OCA training, conducted using the full range of counter-air systems, both friendly and adversary - see Reuter, 'Red Flag', pp.130-134.

War, significantly, China has begun to conduct Large Force Employment training exercises, venturing as far as Turkey to conduct joint exercises. China wishes to be able to project power at distances it is not currently capable of achieving, and is keen to learn Western doctrine and tactics.[536]

When planning for and conducting a counter-air campaign, planners are required to consider a number of aspects, not least, the capabilities of any potential adversary. There are, however, some axioms that do not change, or at least have not to date. Control of the air itself is rarely achievable by air assets alone. The forces required for adequate control of the air will vary, depending on the threat. The level of control required will depend on the level of risk/attrition the planners are willing to accept.[537] Component elements of a counter-air package will include the full range of combat air and support assets, and infrastructure; included are all the ground- and space-based effects that make up a campaign. These assets will consist of:[538]

- Air-to-air, SEAD and strike-attack aircraft. Unless capable of achieving air dominance, SEAD and strike assets will be behind the fighters.
- C4ISTAR, ELINT assets. Used in friendly airspace, until control of the air is gained, unless capable of self-protection.
- AWACS – Used to provide battlespace management; sometimes combined with an AEW role. Positioned well behind the combat air, although, sometimes pushed forward, if protection is offered by combat air.
- AAR – Positioned well behind the combat air, although, sometimes pushed forward, if protection is offered by combat air.
- Ground- and sea-based radar units; own IADS, for land- and sea-based defence; EW, communications, space assets, and all support personnel.

All air assets can 'retrograde' (fly in the opposite direction to enemy fighters) if required – however, this would normally render them incapable of providing a viable service.

<u>Basing</u>

Close and secure land bases and sometimes carriers, close enough to an adversary's centre of gravity, are necessary to generate sufficient sorties. If these do not exist, against

[536] See Jim Wolf, 'China Mounts Air Exercise with Turkey', *Reuters,* http://www.reuters.com/article/2010/10/08/us-china-turkey-usa-idUSTRE6975HC20101008, (accessed 14 March 2011).

[537] For guidance on the considerations for military risk, see DCDC, *Campaign Planning: Joint Doctrine Publication 5-00*, 2nd Edition, Shrivenham: UK Ministry of Defence, 2008, Annex 2H – Military Risk.

[538] *AP 3002– Air and Space Warfare*, Chap 7, pp.3-12.

an adversary capable of projecting force at great distances, fighters must attempt to dominate the air battle from bases situated at suboptimal distances. This presents significant difficulties, particularly if an opponent has a quantitative advantage. Due to a normal fighter aircraft's size, fuel constraints limit most fighter operations to within 500 nm of the battle area, from both AAR orbits, and operating bases, land and sea.[539] Previously mentioned, AAR can greatly extend a fighter's on-task time; however, AAR assets may themselves be forced to operate in contested airspace. According to John Stillion and Scott Perdue in *Air Combat, Past, Present and Future*, a RAND brief of a potential conflict between the US and China, an example of the distances combat aircraft travel was demonstrated in the 2003 Gulf War, where the fighter distance to Baghdad was approximately 550 nm, while during the 1999 Kosovo conflict, the fighter distance to Belgrade was approximately 350 nm.[540] All of these operations were backed with the full gamut of support required, including large numbers of AAR, ELINT and C2 assets. Importantly, neither conflict offered a significant counter-air threat to coalition forces.

This RAND brief uses a possible China versus Taiwan conflict as an example. The analysis describes the PLAAF as having 27 bases within 500 nm of the Taiwan Strait, while the USAF has just one – Kadena, in Japan.[541] This analysis goes on to state that current and planned US combat aircraft fleet range/payloads are optimised for a Cold War scenario, centred on a Soviet invasion into Central Europe. The scale of Western Pacific theatre is significantly larger.[542] If US CSG are forced to remain at distance from a Taiwan conflict, then it is axiomatic that operating current and planned US combat aircraft in the Western Pacific will result in low sortie rates, thus reducing effective combat power, while still demanding a huge AAR refuelling task. China would also have the capability to target bases like Kadena, and others further afield, potentially rendering them ineffective.[543]

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[539] The Tornado F-3, for example, could operate at 500 nm from base for approximately 1 hour, if fitted with large external fuel tanks - see Squadron Leader RAF Brian Handy (ed), *Royal Air Force Aircraft & Weapons*, London: DCC(RAF) Publications, 2003, pp. 4-5. See also, Work and Ehrhard, *op. cit*., Part III, p.25.

[540] See Stillion and Perdue, *op. cit.,* PPF.14. This RAND brief (Power Point presentation) is available from internet sources. Although it is caveated 'Unclassified/FOUO/Sensitive', it has been cited in a number of academic works, including, Barry Watts, *The F-22 Program in Retrospect,* Washington, DC: Center for Strategic and Budgetary Assessments, 2009, http://www.csbaonline.org/publications/2009/08/the-f-22-program-in-retrospect/, (accessed 4 October 2010), p.6. Although not the panacea for future conflict scenarios, it does contain some extremely thought provoking analysis. Permission has been granted to the author to cite this presentation, (Email – Lauren Skrabala, Permissions Officer, RAND Corporation, 14 November 2012).

[541] Stillion and Perdue, *op. cit*., PPF.14.

[542] *ibid.*, PPF.15.

[543] *ibid.,* PPF.8. This part of the RAND analysis gives an indication of ranges that the PLAAF can target out to. Significantly, Flanker aircraft armed with ASCM are effective out to 750 nm, while its Medium Range Ballistic Missiles can taget to 1500 nm.

Stealth

Stealth has its roots in long-standing efforts to reduce the detection of military aircraft through camouflage paint schemes. However, as electronic sensors have replaced the eyes of pilots as the primary means of tracking other aircraft, more intricate means of defence were needed. Stealth has evolved as a complex design philosophy to reduce the ability of an opponent's sensors to detect, track and attack an aircraft.[544] The design of stealth systems does, however, require careful trade-offs, some of which can impact on other areas of aircraft performance. A range of technologies are combined in order to make an aircraft difficult to detect by radar. These include a smooth surface design, radar absorbent materials (RAM), and electronic support and protection.[545] The aircraft's RCS reduces the range at which ground- and air-based radars can detect the aircraft. RAM absorbs most of an adversary's radar's energy, with the aircraft's suitably designed shape redirecting much of the remaining power away from the radar source – in theory. Where possible, engines are incorporated into the fuselage with air intake and exhaust ducts placed on the top of the aircraft in order to reduce the heat signature, and hide the jet engine's compressor blades from radar detection, impeding Non-Cooperative Target Recognition techniques.[546]

The experience of both Vietnam and the 1973 Arab-Israeli Wars was the single strongest factor in encouraging the development of stealth aircraft.[547] Soviet supplied SAM systems accounted for a large number of US and Israeli aircraft. A Central Intelligence Agency (CIA) report from1968, declassified in 2007, details the lengths the Soviet Union went to in order to supply SAM systems to the North Vietnamese regime.[548] The Egyptians, for

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[544] For a background to development of stealth applications, see Belcher, *op. cit.*, pp.292 -294. An example of the significance of a stealth advantage is where a fighter with an RCS of less than 0.1-m^2 could target a conventional fighter, who's RCS is 5-m^2 for more than 60 seconds before the conventional fighter can fire an AAM. The F-22's RCS is considered to be in the 0.001- to 0.1-m^2 range - see *ibid.,* pp.501-502.

[545] There are four basic techniques for reducing RCS: Shaping; Radar absorbing materials; Passive cancellation, and Active cancellation – see Eugene Knott, John Shaeffer, and Michael Tuley, *Radar Cross Section*, Second Edition, Raleigh, NC: SciTech Publishing Inc, 2004, p.270.

[546] For analysis of the fundamentals of stealth, see Schleher, *op. cit.,* pp.508-514,

[547] The Israeli Air Force lost 50 aircraft in the first three days of the 1973 war – see Grant, 'The Bekaa Valley War', p.58. Although the majority of US surface-to-air losses during the Vietnam War were from Anti-Aircraft Artillery (AAA), the huge number of SAM launched at US aircraft hindered their operations – see, Spencer Tucker (ed), *The Encyclopedia of the Vietnam War: A Political, Social, and Military History*, Santa Barbara, CA: ABC-CLIO, LLC, 2011, pp.27-29.

[548] See Directorate of Intelligence, 'Intelligence Report: The Sino-Soviet Dispute on Aid to North Vietnam (1965-1968)', Central Intelligence Agency, 1968, http://www.foia.cia.gov/CPE/ESAU/esau-37.pdf, (accessed 6 September 2012), pp.i-iv.

example, possessed a range of Soviet supplied SAM, including 40 SA-2, 85 SA-3 and 40 SA-6 batteries, with over 400 early warning, acquisition and fire control radars.[549]

Knowledge of the capabilities of Soviet SAM systems led directly to the development of the first truly stealth aircraft, the US F-117 Nighthawk.[550] A product of the Lockheed Corporation's Skunk Works, the F-117 was also the first combat aircraft to use an automatic flight control system capable of controlling every aspect of a mission, from take-off, execution and delivery of weapons.[551] The stunning success of the F-117 during the 1991 Gulf War led Donald Rice, the US Secretary of the Air Force from 1989 – 1992, to predict: '…that by the first couple of decades of the [21st century] every military aircraft flying would be stealth…'.[552] Rice was perhaps overstating things, and probably meant combat aircraft, that is, those that require taking the fight to the enemy. Most current 21st century fighters lack real stealth; only the F-22 Raptor can be classified as truly stealthy. However, China and Russia are making great strides in development of their own fifth-generation fighters, with the J-20, J-31 and PAK-FA.[553]

Although RCS reduction is important, there are limits to the utility of stealth techniques. Since the RCS of an aircraft depends on the angle from which it is viewed, an aircraft will typically have a much smaller RCS when viewed from the front or rear than when viewed from the side or above. In general, stealth aircraft are designed to minimise their frontal RCS. Current technology struggles to allow the contouring of the surface of an aircraft to reduce the RCS equally in all directions, and reductions in the frontal RCS may lead to a larger RCS from above.[554] While a stealth aircraft may be difficult to track when it is flying toward ground-based radar or another aircraft at the same altitude, high-altitude airborne radar or space-based radar may be more successful.[555] These and other detection systems, when their data is fused as part of a NEC system, may offer the counter to stealth technology.

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[549] Edgar O'Ballance, *No Victor, No Vanquished: The Yom Kippur War*, London: Presidio Press, 1978, pp.281-282.

[550] Ben R. Rich and Leo Janos, *Skunk Works*, Boston: Little, Brown and Company, 1994, p.95.

[551] *ibid.*, p.95.

[552] *ibid.,* p.99.

[553] Abdullah, *The Military Balance: 2013*, p.254.

[554] Knott, Shaeffer, and Tuley, *op. cit.,* p.271.

[555] See Schleher, *op. cit.,* p.506, Table 8.6.

Counters to Stealth

While stealth techniques are considered very important to achieving control of the air, whether they are crucial is open to debate.[556] The basics of RF stealth, in particular, are well understood by scientists. Many publications describe the fundamentals of sensor and platform physics.[557] There is a general perception that stealthy aircraft are undetectable. This is not the case, as they are just difficult to detect at certain radar frequencies.[558] Their stealth qualities are optimized against X-Band (fighter radars generally work in this frequency band, 8 – 12 GHz) engagement radars.[559] According to the designers of the F-117, for example, it could be detected by the Iraqi IADS, but it could not be tracked accurately enough to allow weapon engagement.[560]

Although knowledge of the principles of stealth may be relatively easy gained, implementation of stealth technology is another matter entirely. Some of the materials used require special and costly maintenance. The manoeuvrability of an aircraft can be compromised by the introduction of stealth design features, which may also impact on operational efficacy. Sensors pose a particular problem for stealth aircraft, in particular, large radars used by conventional aircraft.[561] As a result, future air-to-air missions may largely rely on passive detection of transmissions by hostile aircraft, as well as IR tracking. The use of on-board EA and radar systems emits RF energy that can be detected by adversary systems. Other means of establishing situational awareness are therefore preferred. Aircraft for attacking targets on the ground face a similar problem. Any aircraft, including stealth, will be vulnerable to detection by Infrared Search and Track (IRST) systems. The natural heating of an aircraft's surface makes it visible to this type of system. The faster an aircraft flies, the hotter it gets, making it easier to detect through IR means.[562]

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[556] Although stealth was not at the top airframe requirement of responses to the author’s questionnaire, it is interesting to note that, in the responses to a different question, 63% of interviewees view stealth in 2040 as crucial, 30% as desirable, with 7% stating that it would not be crucial. Most believe that stealth will play an important part, but it will need to be in all domains, not just the RF, but also in the IR and visual spectrums.

[557] For example, for an excellent overview of aircraft stealth, see Rebecca Grant, *The Radar Game: Understanding Stealth and Aircraft Survivability*, Arlington, VA: IRIS Independent Research, 1998, pp.22-37.

[558] See Schleher, *op. cit.,* p.507.

[559] For a description of the importance that radar frequency has in detecting different shapes and sizes, see Eugene Knott, 'Radar Cross Section', in *Radar Handbook*, Second Edition, Merrill Skolnik (ed), Boston: McGraw-Hill, 1990, pp.11.2-11.17.

[560] See Rich and Janos, *op. cit.*, pp.99-101.

[561] Knott, Shaeffer, and Tuley, *op. cit.,* pp.407-408.

[562] For a background on Infrared Search and Tracking System (IRSTS), see N. Acito and G. Corsini, 'Airborne Threat Detection in Navy IRST Systems', *Vision, Image and Signal Processing, IEE Proceedings* 152, no. 1, 2005, pp.45-51.

Although Forward Looking Infrared (FLIR) can be used for detecting targets of known general location, they are ill suited for searching for targets over a wide area. In order to locate targets, stealth aircraft may rely on airborne Laser Detection and Ranging (LADAR), although such a sensor may prove of limited utility in poor weather.[563]

A number of countries produce radar systems that have been specifically developed to detect LO/stealth aircraft. The Belorussian Nebo SVU VHF Digital AESA radar is an example, and is in service and available for export. The Nebo SVU is being integrated into a mobile VHF acquisition radar. A Belorussian military export company, Rosoboroexport, describes the Nebo SVU radar as:

> The Nebo-SVU radar is designed to automatically detect…and track a wide range of modern airborne platforms, including strategic and tactical aircraft…ballistic targets such as small-size hypersonic cruise missiles warheads, low-observable targets, in particular those embodying stealth technology…[and]to detect active EA threats…[564]

Its digital AESA design allows accurate bearing measurement of altitude and range; this accuracy may be enough to allow mid-course updates for long-range SAM or AAM, acting as part of a third-party-targeting system. Another novel approach to counter-LO has been the development of passive systems such as the Czech VERA-E, which uses radar, television, cellular phone and other available signals of opportunity reflected from stealthy aircraft, to find and track them.[565]

Although stealth may not be the panacea, its importance is generally acknowledged; there are dissenters, however. According to Dr Carlo Kopp, *Air Power Australia*, the US needs, '…to start thinking about which strategic niche they wish to occupy in 2020. The stealth monopoly cannot last forever, and the US must now confront the prospect of a future in which the asymmetric advantage of US stealth is no longer absolute, but rather incremental'.[566] There are contrary views. Barry Watts, in *The Maturing Revolution in Military Affairs*, notes there is a view that, '…the balance between information acquisition and information denial will swing dramatically in favor of the former…there will come a time in the not-too-distant future when the SAM will almost always win against air-breathing penetrating platforms…'.[567] Watts argues, however, that this scenario is unlikely. He contends that a definite answer would require access to data on current and projected

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[563] Albert V. Jelalian, *Laser Radar Systems*, Norwood: Artech House, 1991, pp.1-3.

[564] Rosoboroexport, 'Surveillance Radars', *Rosoboroexport*, 2010, http://www.roe.ru/cataloque/airdef_cataloque.html, (accessed 14 May 2010), p.42.

[565] See Streetly, *op. cit.,* pp.325–326.

[566] Dr Carlo Kopp, 'When America's Stealth Monopoly Ends, What's Next?', *Air Power Australia NOTAM*, 4 March 2009, http://www.ausairpower.net/APA-NOTAM-040309-1.html, (accessed 1 May 2009).

[567] Watts, *The Maturing Revolution in Military Affairs,* p.28.

capabilities for reducing radar signatures and countering advanced SAM that are highly classified, which means that comment not totally informed should be treated with scepticism.[568] Watts further suggests the shift to digital AESA radars and continuing growth in computer processing capabilities which aid the attacker can also be exploited by stealthy adversaries.[569] The F-35 JSF's planned fusion of sensors, aligned with NEC, for example, gives the F-35 an ability to react automatically to threats. The F-35's AESA radar can be used for EA of adversary IADS, as well as DRFM jamming capabilities that offer the potential to increase survivability.[570] Although the use of active AESA radars and DRFM jammers could alert adversary systems, there will be occasions when their use is warranted. For example, DRFM techniques can be utilised against both aircraft and AAM radars.[571]

Watts writes that the F-35, like the F-22, has been developed for survivability in daytime operations and will probably operate in networked groups of four or eight aircraft, greatly multiplying their capacity to overcome adversary IADS, such as Russian S−300/400/500 class SAM.[572] Chinese SAM systems, such as the HQ-9, which is based on the S-300, have similar capabilities.[573] It is this class of SAM that presents a counter-air planner with the greatest test. Although stealth will undoubtedly aid the counter-air mission, it is but one part of the matrix to their mission success. Essentially, Watts believes that the US decision makers are committed to the JSF programme, and are able to evaluate the capabilities of all-aspect LO into the 2040s.[574]

Stealth's primacy may well be tested, with the result that other techniques, systems and tactical doctrine are required. As with any game-changing technology, such as the tank during World War I, and the development of radar in the 1930s, other industrial based societies will eventually develop the same types of systems, and counter-systems. Science is not the preserve of certain countries; however, having the economic and industrial base required to develop this advanced technology may limit the number of countries capable of

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568 *ibid.*

569 *ibid.*

570 US Senate Armed Services Committee, 'Statement of Mr. William Balderson, Deputy Assistant Secretary of the Navy (Air Programs), before the Airland Subcommittee of the Senate Armed Services Committee, on Fiscal Year 2008 Navy/Marine Corps Aviation Programs', 26 April 2007, http://www.globalsecurity.org/military/library/congress/2007_hr/070426-balderson.pdf, (accessed 25 May 2010), p.4.

571 Schleher, *op. cit.,* pp.293-294.

572 Watts, *The Maturing Revolution in Military Affairs,* pp.28-29. For details of S-300/400/500 series, see Streetly, *op. cit.,* pp.216-227.

573 Streetly, *op.cit*.,. p.365.

574 Watts, *The Maturing Revolution in Military Affairs,* pp.29-30. It is impossible to verify the F-35's capabilities in the unclassified domain of available information.

doing so. Whether stealth is the panacea to obtaining control of the air is debateable, nonetheless. Against a peer or near-peer adversary however, there is no doubt that it will cause that adversary to seek ways to counter any advantage that stealth brings. It is perhaps telling that the US will now only have 187 F-22, maximum, in its inventory.[575] Systems will be developed, with the aim of allowing the US to maintain its counter-air supremacy in the coming decades. In 2009, writing in *The Washington Post*, the Secretary of the US Air Force, Michael Donley, and the USAF Chief of Staff, General Norton Schwartz, in a joint statement, stated that, 'Within the next few years, we will begin work on the sixth generation [fighter] capabilities necessary for future air dominance'.[576] Since this statement, Donley speaking to a USAF journalist, has indicated that, although there is no sixth- generation programme, '…the early pieces of what would constitute a program are already out there'.[577] Although there is no universal definition of what 'sixth generation' entails, a definition used by some aviation journals, for example, the US *Air Force Magazine* is – *'…*extreme stealth; efficient in all flight regimes…possible "morphing" capability; smart skins; highly networked; extremely sensitive sensors, optionally manned, [and utilising] directed energy weapons'.[578] Optionally manned and DEW are particularly interesting aspects.

Weapon Systems, Sensors and Enablers

It may seem a fairly basic principle, but in order to engage and destroy adversary aircraft, these need first to be detected, tracked and identified. Detection and tracking information on hostile aircraft may be obtained from a variety of sources: for example, visual sightings, IR or acoustic monitoring, conventional radar, including airborne radar, over-the-horizon radar, ELINT and Electronic Support (ES) systems, and spaced-based detection systems.[579] Fighter aircraft have relied on airborne radars, positioned at the front of the aircraft, since WW II. Referred to as air-intercept radars, these have evolved from very basic pulse systems, into the sophisticated AESA systems used today.[580] Already in use,

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[575] 'The F-22 Raptor: Program & Events', *Defense Industry Daily*, 2012, http://www.defenseindustrydaily.com/f22-raptor-procurement-events-updated-02908/#program, (accessed 2 February 2012).

[576] Michael Donley and Norton Schwartz, 'Moving Beyond the F-22', *The Washigton Post*, 13 April 2009, http://www.washingtonpost.com/wp-dyn/content/article/2009/04/12/AR2009041202268.html, (accessed 19 July 2012).

[577] Colin Clark, 'No Sixth Gen Fighter Coming: Donley', *DoD Buzz: Online Defense and Acquisition Journal*, 22 February 2011, http://www.dodbuzz.com/2011/02/22/no-sixth-gen-fighter-coming-donley/, (accessed 2 August 2012).

[578] John A. Tirpak, 'The Sixth Generation Fighter', *Air Force Magazine* Vol 92, no. 10, p.40.

[579] *AP 3002 – Air and Space Warfare,* Chap 7, p.8.

[580] Phillippe Lacomme and others, *Air and Spaceborne Radar Systems*, Norwich, NY: William Andrew Publishing, 2001, pp.1-2.

AESA are set to become critical in target detection, with other systems being incorporated, as part of an NEC. The information from these systems needs to be merged into a recognised air picture (RAP), which can then be disseminated to all agencies and forces involved in counter-air operations.

A counter-air system is not entirely air-to-air centric. It will normally consist of two complementary components: surface-to-air defences, if protecting land- or sea-based assets, and air-to-air systems.[581] Surface-to-air defences consist of SAM systems and AAA, and the associated detection systems; they allow high readiness states to be maintained over long periods, giving quick response and, in certain cases, they can be used to counter ballistic missiles, for example, the American Patriot SAM system, which was used to some effect during the 1991 Gulf War against Iraqi Scud missiles, although its efficacy has been questioned.[582] However, in comparison to fighter aircraft, SAM have limited range and low mobility, and therefore relatively large numbers of surface-to-air defence systems may be required. These air defences can be fully effective only if they are integrated into the wider air defence organisation. They not only help to protect air installations from air attack, but also form an integral part of the counter-air campaign by inflicting attrition on the enemy air forces.[583] Fighter aircraft are the ‘front-line’ of counter-air. They are flexible and reusable and can be switched to tasks other than counter-air, should the operational situation demand it. If required, fighter aircraft can be used to protect very large areas or be concentrated rapidly to counter enemy saturation raids. They may also be used to identify targets positively before engaging them, if no other means is available.[584]

The primary current means of destroying adversary aircraft in air-to-air engagements is by the use of AAM, both RF and IR; their importance in achieving the endgame – that is destroying attacking aircraft, has been crucial since the Vietnam War.[585] Most fighters are also equipped with an air-to-ground gun, normally the same gun used for air-to-air. Having the ability to engage an adversary at long-range, classically known as BVR, can enable an attacker to stay outside an enemy’s weapon systems engagement zone. This advantage is

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[581] For analysis of the constituent parts of a counter-air system, see RAF Air Warfare Centre, *AP 3002 - Air Warfare*, 2nd Edition, Chap 2, Section 2, ‘Counter-Air Operations’, pp.43-54.

[582] The US Army initially assessed Patriot to be 96% effective, finally reducing this to 61%. Even this success rate is questioned – see George N. Lewis and Theodore A. Postol, 'Technical Debate over Patriot Performance in the Gulf War: American Physical Society Panel Correctly Rejects Criticisms of Analysis Showing Patriot Failed to Destroy Scud Warheads', *Science & Global Security* Vol 8, 2000, pp.315-316.

[583] See *AP 3002 - Air Warfare,* 1st Edition, p.52, para 15c.

[584] *ibid.,* p.52, para 15a.

[585] Few air-to-air guns kills have been achieved since the Vietnam War. For analysis of Western air-to-air kills since 1965, see Chapter 5.

negated, however, if an adversary also has a BVR capability; in this case, one's own kinematic advantage and AAM stand-off supremacy is paramount.[586] If a fighter's BVR AAM are negated, or a fighter is outnumbered, it is probable that an air-to-air engagement will be forced to enter into the visual arena. The first part of WVR combat will include the exchange of AAM, when fighter crews have visual of each other. If this happens, although RF AAM can be used, more manoeuvrable IR AAM become the primary means of engaging adversary aircraft, with the last resort being the AAG.[587] The AAG is generally seen as a tertiary weapon, used if both RF and IR AAM fail.[588]

Electronic Warfare

Since the advent of radar in World War II, EW has played a prominent role in air power, particularly, in counter-air tasks. The Vietnam War saw the use of EW increase dramatically, when it became clear that normal 'kinetic' methods would not achieve the desired result, that is the nullification of the North Vietnamese IADS.[589] Although this was never achieved, once EW techniques were harnessed, US airborne losses decreased dramatically.[590] The aim of EW is to disrupt an adversary's use of the EMS at critical points, while ensuring continued friendly use of the EMS.[591] EW is defined as any military action involving the use of the EMS, including DEW, to control the EMS or to attack an enemy. This is not limited to radio or radar frequencies, but includes IR, visible, ultraviolet, and other less used portions of the EMS.[592] The three major components of EW are EA, Electronic Protection (EP), and Electronic Support (ES).[593] EA is the component of EW involving the use of the EMS, DEW, or anti-radiation weapons with the intent of degrading, neutralising, or destroying an adversary's combat capability. EA also prevents or reduces an enemy's use of the EMS. EA includes direct attack with high-speed anti-radiation missiles; active applications such as decoys, noise jamming, deceptive jamming, expendable miniature jamming decoys, HPM and DEW are also employed. Electronic emission control and LO technologies are passive applications of EA.[594] EP includes the actions taken to protect personnel, facilities, and equipment from EW. Examples of EP

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[586] See Schreiber, Stock, and Winston Bennett, *op. cit.,* p.9. See also, Shaw, *op. cit.,* pp.51-52.

[587] For an explanation on how AAM are employed, see Shaw, *op. cit.,* pp.45-52.

[588] For AAG employment techniques, see *ibid.,* pp.15-23.

[589] Grant, *The Radar Game: Understanding Stealth and Aircraft Survivability*, pp.17-20.

[590] See US Air Force Doctrine Center, *op. cit.,* p.4.

[591] *ibid.*, p.16.

[592] For a definition of EW, see *Electronic Warfare – Threats, Requirements, and Principles*, p.1.

[593] EA, ES and EP are relatively new definitions, replacing the old ECM, ESM and ECCM nomenclature, see *ibid.*, p.xi.

[594] US Air Force Doctrine Center, *Electronic Warfare*, pp.7-8.

include radar frequency agility, and changing pulse repetition frequency.[595] ES is that part of EW that intercepts, identifies, and locates sources of radiated electromagnetic energy for the purpose of threat recognition. ES information can be correlated with other ISR information to provide a more accurate picture of the battlespace, which may then be developed into an electronic order of battle for gaining situational awareness; it may also be used to develop new countermeasures.[596]

The importance of EW is generally understood by military planners; however, the significance that modern, easily obtained, EA systems have in denying the F2T2EA cycle is perhaps not so readily understood. The effectiveness of relatively simple DRFM jammers, for example, can have devastating consequences on the ability of a force to gain control of the air.[597] The effects of various EW techniques can significantly disrupt an IADS, sensors, communication links, weapon systems, and C2. Jamming, chaff, and decoys degrade an adversary's ability to conduct the F2T2EA cycle. Even if targets are detected through this wall of confusion caused by EA techniques, and AAM weapon systems get through to their intended targets, they lose some effectiveness; their likelihood of actually destroying the target can be greatly reduced.[598]

EA techniques have changed the way in which warfare is fought. Every sensor, RF and IR weapon can be affected by EA; mitigating the effect of EA on these systems requires significant effort. The future use and countering of EA systems forms a crucial part of military doctrine. Aligned with weapon systems and sensors, stealth and NEC, EA has become a key element in gaining supremacy in the battlespace.

Cyber-Warfare

Cyber-warfare is another area of importance. The air power environment is extremely dependent upon good data links and communications, in general. With the recent formation of US Cyber Command, the US has emphasised that cyber issues are now part of the spectrum of warfare. The US military was the first to merge its EW areas of interest with those of cyber – described as the 'cyber-electromagnetic contest'.[599] For the purposes of this thesis, however, EW and Cyber will be referred to separately as two different

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[595] *ibid.*, p.9.

[596] *ibid.*, pp.9-10.

[597] Schleher, *op. cit*., pp.293-294. The Russian 'Sorbtsya' and the Chinese 'KG300G' systems, are examples of widely proliferated jammers – see, Streetly, *op. cit*., pp.529 and 565.

[598] EA can affect the AAM fuse, for example, resulting in an early or late detonation, causing a failure – see Shaw, *op. cit*., pp.56-57.

[599] US Army Capabilities Integration Center, *op. cit.,* p.i.

strands. Both disciplines use the EMS, and computer hardware and software. An example of how cyber-attacks can have an effect, is an alleged 2011 attack on Iran's nuclear programme. In 2011, Iran accused the German engineering firm Siemens of helping Israel and the US launch a computer virus to sabotage its nuclear facilities. Both the US and Israel have not denied computer experts' claims that they were behind the development of the Stuxnet Worm.[600]

China is considered by many Western governments to be one of the most frequent practitioners of cyber-warfare. According to *The Washington Post*, 'China is waging a quiet, mostly invisible but massive cyberwar against the United States, aimed at stealing its most sensitive military and economic secrets and obtaining the ability to sabotage vital infrastructure'.[601] A report from the *U.S.-China Economic and Security Review Commission to the US Congress* states, 'Chinese capabilities in computer network operations have advanced sufficiently to pose genuine risk to U.S. military operations in the event of a conflict….A few weeks before a potential conflict over Taiwan, the [PLA] may mount a computer network attack on systems operated by the U.S'.[602] It is likely that many countries, such as China, will seek to utilise computer network attack as a military tool, from ground-, air- and space-based assets.[603]

Command and Control

Any fighting force must have a cohesive and effective C2 system. Its purpose is to integrate all of the various elements of weapon and detection systems into a coordinated entity, ensuring the optimum use of available resources against threats.[604] When working with surface forces within a theatre, in particular, a good C2 system is essential to ensure that joint counter-air assets are employed in a fully coordinated approach. If not, assets can be under-utilised, increasing the possibility of fratricide, which is always of major concern to any air defence unit. C2 can be land-, sea- or air-based, or a combination of

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[600] For an overview of the reported Stuxnet attack, see 'Stuxnet: Targeting Iran's Nuclear Programme', *Strategic Comments - IISS* 17, no. 2, 2011, pp.1-3.

[601] Editorial Board, 'China's Cyberwar', *The Washington Post*, 16 December 2011, http://www.washingtonpost.com/opinions/chinas-cyberwar/2011/12/15/gIQA2Aw1wO_story.html, (accessed 21 December 2011).

[602] Bryan Krekel, Patton Adams, and George Bakos, *Occupying the Information High Ground: Chinese Capbilities for Computer Netwok Operations and Cyber Espionage,* Washington,DC: Northrop Grumman, 2012, http://www.washingtonpost.com/r/2010-2019/WashingtonPost/2012/03/08/National-Security/Graphics/USCC_Report_Chinese_Capabilities_for_Computer_Network_Operations_and_Cyber_%20Espionage.pdf, (accessed 8 March 2012), p.9.

[603] For an assessment of cyber warfare threats, see generally, Martin Libicki, *Cyberdeterrence and Cyberwar*, Santa Monica, CA: RAND Corporation, 2009.

[604] For a description of the requirements of C2, see *AP 3002 – Air and Space Warfare,* Chap 5, pp.1-11.

these. For identification of friend or foe, C2 is critical, unless forces can operate to some level of autonomy. It can be seen, therefore, that taking out an adversary's C2 is an important task, starting in the first stages of a campaign. Conversely, however, having forces with the capability to operate autonomously can mitigate the criticality of C2.[605] It may be prudent, therefore, in certain scenarios, to allow for the C2 to remain functioning.

Network Enabled Capability

Much is made today of the possibilities of NEC/NCW. The aim of NEC is to have superior understanding of the battlefield by virtue of the ability to gather and assess information from many sources – especially in relation to that of an opponent – and act on it. General Rupert Smith believes that NEC has effectively been used since World War II; he states: 'To my mind, from their reconnaissance and analysis to their ability to engage the enemy, RAF Fighter Command fought the first 'network enabled' battle'.[606] Current UK doctrine considers NEC as the underpinning requirement for an IADS, with its *Joint Warfare Publication: 3-63 Joint Air Defence,* stating a Joint AD System as using:

> ….all available sources for surveillance and identification, whether theatre assets or those active or passive sensors provided by maritime, land, air or space based platforms acting as an integrated and interoperable system which provides the highest level of air situational awareness throughout the relevant area of operations.[607]

An example of the force multiplier attributes of NEC is the introduction of the JTIDS. In the mid-1990s, the USAF conducted the JTIDS Operational Special Project. This trial tested the capabilities of the F-15C equipped with voice-only communications, compared with F-15C equipped with voice and JTIDS Link-16 TDL communications in tactical air-to-air combat; more than 12,000 sorties were undertaken. Blue offensive counter-air packages varied in size from two to eight F-15Cs. In all cases, the packages were controlled by AWACS aircraft. Engagements ranged from two Blue fighters on two Red fighters, to eight Blue fighters on 16 Red fighters. On average, Blue offensive counter-air packages equipped with JTIDS achieved a two-and-a-half time's improvement in kill ratio, over those that used traditional voice communications only.[608] This is a significant dichotomy. Essentially, aircrew's situational awareness is significantly enhanced by the use of JTIDS, enabling all participants to share the information they possess, and

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605 See *ibid.,* Chap 2, p.44.

606 Rupert Smith, *The Utility of Force: The Art of War in the Modern War*, London: Penguin Books, 2006, pp.133-134.

607 UK Ministry of Defence, *Joint Warfare Publication 3-63: Joint Air Defence*, p.1.10.

608 See Daniel Gonzales and others, *Network-Centric Operations Case Study: Air-to-Air Combat with and without Link 16*, Santa Monica, CA: RAND Corporation, National Defense Research Institute, 2005, p.xv.

allowing a fuller air picture to be established.[609] Once JTIDS was installed in all the Tornado F-3s, it became one of the best counter-air aircraft in the West's inventory, despite its inherent deficiencies, such as its lack of agility in the visual environment.[610] NEC is more than one system; it encompasses all information nodes, enabling situational awareness to be gained, actions to be taken, and reassessment to be made – a classic example of Boyd's OODA Loop.[611]

Integrated Air Defence System

An IADS fuses all anti-aircraft sensors, including radar, visual observers, anti-aircraft weapons, such as AAA, SAM, air superiority fighters and interceptors, under a common system of C2. Today's battlefield, in many respects, starts as a duel between the IADS and the SEAD campaign against it. During World War II, the RAF's Fighter Command benefited from an early version of an IADS. This was developed into a genuinely NEC, as radar and radio became available in the interwar period. Data from radar stations and Observer Corps posts was collected, filtered, fused, analysed and disseminated, using a network of land-lines and ground-to-air radio. This early example of NEC resulted in the RAF being able to make decisions quickly, getting inside the Luftwaffe's OODA Loop.[612] It would be fair to say that during World War II, the UK's home-defence radar network was one of the key factors why the Luftwaffe failed to dominate the RAF, resulting in the cancellation of Operation Sea Lion, the German plan to invade Britain, once control of the air was achieved.[613] The term IADS had not yet been invented, but more importantly, the Germans did not see the British system as a system. They saw airfields and radars, but did not grasp that the most critical and vulnerable parts were the control centres.[614]

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[609] For a description of JTIDS capabilities and the RAF's involvement in early joint US-UK trials, see Reuter, 'Joint Tactical Information Distribution System', pp.16-17.

[610] *ibid.* See also p.149, where Gp Capt Richard Powell describes the utility of JTIDS in Operation TELIC, during the 2003 Gulf War.

[611] For a discussion on the relevance of NEC and it's place in the concept of an RMA, see Singer, *Wired for War*, pp.179-196.

[612] See *AP 3000: British Air and Space Power Doctrine*, Chap 4, p.65.

[613] Churchill described the necessity for Germany to gain both air and sea superiority, but was unable to do so, thereby making Operation Sea Lion untenable - see Winston Churchill, *The Second World War: Their Finest Hour*, Vol. II, London: The Folio Society, 2000, Chap 15, *Operation Sea Lion*, pp. 242-252. John Warden also views that the Battle of Britain was a classic example of the Germans choosing the wrong 'Centre of Gravity' - see *Warden, op. cit.,* pp.34 and 40-42.

[614] The Luftwaffe concentrated its resources initially against RAF airfields, switching to cities such as London, taking the pressure off the RAF's radar systems and C2 - see John Terraine, *The Right of the Line: The Royal Air Force in the European War 1939 - 1945*, London: Hodder and Stoughton, 1985, p.209.

A modern IADS has multiple layers of sensors and defensive systems. An example is in the protection of US naval CSG, in which the outermost ring consists of fighters and well-escorted airborne radar aircraft, with the next ring made up of long-range SAM.[615] A further example is the protection of key C2 centres, or nuclear facilities. The critical nodes that comprise an IADS, such as its C2 links, can be considered the centre of gravity. Attacking these nodes may well render an IADS toothless, without having to negate the radar and missile sites, or indeed, the fighters themselves.[616] As already established, a functioning IADS is only as good as its C2/NEC.

Boyd's OODA Loop and its Relevance to NEC

At this point it is worth examining the concept of Colonel John Boyd's OODA Loop and its relationship with NEC/NCW, and the importance it plays in modern warfare and situational awareness. Also known as the 'Boyd Cycle', often quoted by many military commanders and academics, Boyd's OODA Loop aims, '…to create menace and uncertainty and mistrust, then…to exploit and magnify the presence of these disconcerting elements… '.[617] The OODA Loop is a concept that is sometimes misunderstood. Fran Osinga, in *Science, Strategy and War: The Strategic Theory of John Boyd,* offers the view that: 'Controversy and misperception nevertheless surround Boyd's work. Like Clausewitz and Sun Tzu, his work is more heard than read or understood. Very few people have actually worked their way through the presentations'.[618] Commenting on the general lack of appreciation of Boyd's wider works, Mark Safranski, in *The John Boyd Roundtable: Debating Science, Strategy, and War,* views that other than the OODA Loop, '…the corpus of Boyd's work is well known to a relatively small number of his collaborators, reformers, theorists and military officers who were personally influenced by Colonel Boyd'.[619]

Lt Gen David Fadok, Commander and President, the USAF Air University in 2012, in his Master's thesis, *John Boyd and John Warden: Air Power's Quest for Strategic Paralysis,* compares the theories of Boyd and Warden. Fadok views Boyd's OODA Loop theory:

> …[as] process-oriented and aim[s] at psychological incapacitation. He speaks of folding an opponent back inside himself by operating inside his observation-orientation-decision-action

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615 For the requirements of a layered defence for both land- and sea-based forces, see - US Joint Chiefs of Staff, *Joint Publication 3-01: Countering Air and Missile Threats*, Washington, DC: US Department of Defense, 2012, http://www.dtic.mil/doctrine/new_pubs/jp3_01.pdf, (accessed 30 November 2012), *Defensive Counter-Air Planning*, p.V2, para 2(b) 5.

616 See Warden, *op. cit.,* p.44.

617 Coram, *op. cit.*, p. 334.

618 Osinga, *Science, Strategy and War*, p.5.

619 Thomas Barnett, 'Forward', in *The John Boyd Roundtable: Debating Science, Strategy, and War*, Mark Safranski (ed), Ann Arbor, MI: Nimble Books LLB, 2008, p.vi.

> (OODA) loop. This severs the adversary's external bonds with his environment and thereby forces an inward orientation upon him. This inward focus necessarily creates mismatches between the real world and his perceptions of that world. Under the menacing environment of war, the initial confusion and disorder degenerate into a state of internal dissolution which collapses his will to resist.[620]

Fadok's summation captures the crux of Boyd's OODA Loop; however, Boyd's work has and continues to divide opinion. According to Robert Coram, in his biography of Boyd, Boyd is regarded by some as the most important strategist of the 20th century, if not since Sun Tzu.[621] Others, such as the military theorist Colin Gray, are more circumspect. Gray views Boyd's OODA Loop to be either a, '….banal statement of the obvious, or panacea – take your choice…'.[622] Gray acknowledges, however, that, 'It is a sound idea, but as the philosopher's stone for victory at all levels of warfare it is distinctly sub-Clausewitzian'.[623]

Boyd developed the OODA Loop concept over many years. It began with the writing of a sixteen-page essay, *Destruction and Creation,* in 1976. Grant Hammond, in *Patterns of Conflict: John Boyd and American Security,* writes that, '*Destruction and Creation* is the culmination of a quest to find scientific, mathematical, and logical verification for principles that Boyd intuitively knew to be true. Thus tested and refined, it became the basis for most of his thought thereafter'.[624] Chuck Spinney, a close friend and colleague of Boyd's, believes that, '"Destruction and Creation" became the intellectual foundation of his monumental study of competition and conflict – although at the time, he had no idea where his philosophical musings might take him'.[625] Boyd spent the next 20 years exploring and expanding on the ideas expressed in *Destruction and Creation;* the result was *A Discourse on Winning and Losing.* Originally referred to by Boyd as *Patterns of Conflict*, this work evolved from a slide presentation of 90-minutes, to one eventually of over 13-hours. Containing 193 slides, it covers a wide range of ideas, including historical data of social forces, political motivations and technologies, with Boyd's own interpretations and

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[620] Major David S. Fadok, USAF, *John Boyd and John Warden: Air Power's Quest for Strategic Paralysis*, Maxwell Air Force Base, Alabama: Air University Press, 1995, p.v.

[621] Coram, *op. cit*., p.445.

[622] Gray, *Another Bloody Century*, p.203.

[623] *ibid.,* p.191.

[624] See Grant T. Hammond, *The Mind of War: John Boyd and American Security*, Washington: Smithsonian Books, 2001, p.118. See also, Grant T. Hammond, 'From Air Power to Err Power: John Boyd and the Opponent's Situational Awareness', in *Air Power Leadership: Theory and Practice,* Peter W. Gray and Sebastian Cox (eds), London: The Stationery Office, 2002, pp.107-128, where Hammond reviews Boyd's OODA Loop, and its implications on an opponent's situational awareness.

[625] See Chuck Spinney, 'Genghis John', 1998, http://pogoarchives.org/labyrinth/01/01.pdf (accessed 11 August 2012), p.6. Spinney describes Boyd's fight with the USAF and DoD hierarchy to act on his ideas, which included a great deal of advice on what characteristics the next-generation of fighter aircraft should have, as well as his OODA Loop concept.

questions, illustrating how these affect the process of winning and losing.[626] Although available via websites, these slides have not been officially published, but can be freely studied. However, as Coram, quite axiomatically, observes: '….they are not easily interpreted, and require some explanation'.[627] Colonel James Burton USAF (Retd), believes, '*A Discourse on Winning and Losing* will be regarded as the 20th century's most original thinking in the military arts. No one, not even…Clausewitz… Sun Tzu, or any of the past masters of military theory, shed as much light on the mental aspects of conflict as Boyd'.[628]

Hammond writes that, '[Boyd's] intent was to unveil the character of conflict, survival and conquest'.[629] Boyd, at heart a fighter pilot, used the analogy of air-to-air combat to describe the requirement of being able to lose energy and gain energy more quickly than the enemy, when in visual combat.[630] Boyd believed these fast transients of changing direction, speed, and altitude equated to operating at a faster tempo than an adversary. Boyd described this as getting inside an adversary's OODA Loop.[631] Osinga's analysis of *Patterns of Conflict* concludes that, '…Boyd offered his audience a new look at military history…Applying the process of destruction and creation to his investigation, [Boyd] uncovers underlying dynamics of each category of warfare and expresses these in an increasingly abstract and conceptual way'.[632] Boyd's massive brief introduces the concept of the OODA Loop almost at the beginning. In slide 5, *Idea Expansion,* he states: '[The] Idea of fast transients suggest that, in order to win, we should operate at a faster tempo or rhythm than our adversaries--, or, better yet, get inside [an] adversary's Observation-Orientation-Decision-Action time cycle or loop'.[633] In his conclusion in slide 185, *Central Theme*, Boyd sums up his concept:

> Evolve and exploit insight/initiative/adaptability/harmony together with a unifying vision, via a grand ideal or an overarching theme or a noble philosophy, as basis to: Shape or influence events so that we not only amplify our spirit and strength but also influence the uncommitted or potential adversaries so that they are drawn toward our philosophy and are emphatic toward our success, yet be able to..[o]perate inside adversary's observation-orientation-decision-action loops or get inside his mind-time-space as basis to: Penetrate adversary's

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626 Hammond, *op. cit.,* p.122. For Boyd's complete *Patterns of Conflict* brief, see Boyd, 'John Boyd Compendium', *op. cit.*

627 Coram, *op. cit*., p.329.

628 James Burton, *The Pentagon Wars: Reformers Challenge the Old Guard*, Annapolis: Naval Institute Press, 1993, p.10.

629 Hammond, *op. cit.,* p.122.

630 Boyd was the author of a seminal work on air combat manoeuvring , *Aerial Attack Study* - see Coram, *op. cit.,* pp.112-113. Also, see generally, Capt John Boyd USAF, 'Aerial Attack Study', 1963, http://www.dnipogo.org/boyd/pdf/boydaerialattack.pdf, (accessed 19 November 2012).

631 Hammond, *op. cit.,* p.123.

632 Osinga, *Science, Strategy and War*, p.188.

633 John Boyd, 'Patterns of Conflict', slide 5.

> moral-mental-physical being in order to isolate him from his allies, pull him apart, and collapse his will to resist.[634]

Military tacticians generally believe speed is the crucial part of the cycle. While speed is important, it is also argued that it is the orientation phase of the cycle which is critical. Chet Richards, a mathematician and colleague of Boyd, believes that, '….his reading in Zen, particularly *The Japanese Art of War,* confirmed his [Boyd's] emphasis on such concepts as implicit guidance and control, which appears in both *Patterns* and *Strategic Game,* and the overriding importance of Orientation…'.[635] Boyd emphasised that the cycle needed to be executed in such a way as to get inside the mind and decision cycle of an adversary, who is then required to deal with obsolete or irrelevant information, becoming confused and disorientated.[636] Boyd used historical examples to illustrate that his OODA Loop concept was not new, for example, in his *Historical Patterns: Chingis Khan and the Mongols* slide, he states:

> By exploiting superior leadership, intelligence, communications, and mobility as well as by playing upon adversary's fears and doubts via propaganda and terror, Mongols operated inside adversary OODA loops. [The result]…Outnumbered Mongols created impressions of terrifying strength – by seaming to come out of nowhere yet be everywhere. [H]ence, [s]ubversive propaganda, clever stratagems, fast breaking maneuvers, and calculated terror not only created vulnerabilities and weaknesses but also played upon moral factors that drain-away resolve, produce panic, and bring about collapse.[637]

Why is the OODA Loop relevant to NEC/NCW and the development of UCAS? Osinga views that Boyd is the conceptual father of NCW.[638] However, Osinga emphasises, '….that [although] Boyd's influence on contemporary strategic thought has been and continues to be significant…for a full appreciation of that influence, one needs to go well beyond the narrow 'rapid-OODA loop' concept and fully engage with him in his *Discourse on Winning and Losing'.*[639] Although he believes that Boyd himself would not be too keen on the technological aspects of NEC, Osinga emphasises that at the heart of NEC is Boyd's OODA Loop.[640] It is the importance of NEC in driving future doctrine that will be integral to the effectiveness of any UCAS. NEC aims to compress the OODA Loop, enabling cross-cueing and the sharing of information, allowing sustained high tempo F2T2EA operations.

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[634] *Ibid.,* slide.185.

[635] Chet Richards, 'The Origins of John Boyd's a Discourse on Winning and Losing', in *The John Boyld Roundtable: Debating Science, Stratgey, and War*, Mark Safranski (ed), Ann Arbor: Nimle Books LLC, 2008, p.9.

[636] Coram, *op. cit.,* p.334.

[637] See Boyd, *Patterns of Conflict*, slide 28.

[638] Frans Osinga, 'John Boyd and the Strategic Theory in the Postmodern Era', in *The John Boyd Roundtable: Debating Science, Strategy, and War,* Thomas Barnett (ed), 2008, p.37.

[639] *ibid.,* p.50

[640] See Osinga, *Science, Strategy and War: The Stragetic Theory of John Boyd*, pp.150-151.

With data-fusion, from sources such as TDL, ISR assets, and Blue Force Tracker, it offers an RMA, providing greater situational awareness, helping to mitigate ROE and CID constraints.[641] This is vital. During the Vietnam War, for example, US aircrews were forced into visually confirming targets were hostile on most occasions; this, '…required a close approach which in some cases forced the U.S. fighter to pass entirely through the missile launch envelope in order to make the identification. Thus the element of surprise was lost…'.[642] Anderson and Waxman, in *Law and Ethics for Robot Soldiers,* believe that, 'The fastest OODA Loop of the future combat plane is likely to be an automated one…in both flight and weapon functions, and unmanned as well'.[643] This view aligns with the author's. Essentially, effective NEC enables a commander to operate within the 'Boyd Cycle' faster than an adversary without effective situational awareness.

Situational Awareness

Understanding the implications of what is happening in any given scenario is crucial in warfare - that is, having situational awareness. There are a number of interpretations of the meaning of situational awareness. In warfare, situational awareness generally means the view of the whole air, and ground picture, including not only location but also likely future activity, of both friendly and enemy forces. Mica Endsley, in *Theoretical Underpinnings of Situation Awareness: A Critical Review,* defines situational awareness as '…knowing what is going on around you'.[644] This explanation is succinct, and applies to both military and civilian situations; it has huge significance when applied to counter-air operations. Endsley's three-level model of situational awareness: Perception (what is happening), Comprehension (what does it mean), Projection (what should I do about it)—are all applicable to air warfare.[645] According to John Stillion from RAND, situational awareness, '…is a most important aspect of air combat. The pilot, or group of pilots, who maintains the best understanding of where friends and foes are relative to their own position during the

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[641] Blue Force Tracker (BFT) is a computer/GPS based system that provides individual military personnel and commanders with location information of friendly military forces. BFT transmits locations through a satellite terminal, allowing the entire system to monitor the location and progress of friendly forces. This information is consolidated, and updated at a Tactical Operations Centre, then transmitted out to user stations in the field - see Giles Ebbutt, 'Blue-Force Tracking Evolves for the Modern Battlefield', *Defense & Security Intelligence and Analysis: IHS Jane's*, 11 June 2008, http://www.janes.com/products/janes/defence-security-report.aspx?id=1065926194, (accessed 9 September 2010).

[642] Attinello, *Air-to-Air Encounters in Southeast Asia: Volume IV: Analyse,* p.43.

[643] Anderson and Waxman, *op. cit.,* p.4.

[644] Mica R. Endsley, 'Theoretical Underpinnings of Situation Awareness: A Critical Review', *Situation Awareness Analysis and Measurement*, 2000, http://www.satechnologies.com/Papers/pdf/SATheorychapter.pdf, (accessed 15 March 2010), p.2.

[645] *ibid.,* pp.3-4.

confusing, time compressed, air combat engagement will most likely emerge the victor'.[646] A NATO report views that pilots are required to answer many questions during air-to-air combat, including. 'Where am I? Where am I going? Where are the enemies? Where are the enemies going?...Where are friendly aircraft going? What is the aircraft's energy status? What is the status of on-board systems? What is my weapon delivery envelope?'[647] Lynn Carroll, from the AFRL/RHA Warfighter Readiness Research Division, describes situational awareness as:

> .…a pilot's, (or aircrew's), continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast, then execute tasks based on that perception. It is problem solving in a three dimensional spatial relationship complicated by the fourth dimension of time compression where there are too few givens and too many variables. It encompasses the individual's experience and capabilities which affect the ability to forecast, decide and then execute. SA represents the cumulative effects of everything an individual is and does as applied to mission accomplishment. It's what allows you to successfully complete the mission, or to recognize the need to abort. It keeps you out of the dirt and out of someone else's space.[648]

Gaining situational awareness is vital, perhaps the key enabler in air combat. Its importance is understood today; however, it was not until the Vietnam War that the dominant role of situational awareness in war was fully comprehended. Situational awareness is enabled by a number of technologies and skills, NEC and sensors, and, not least, by the acquired skills of those aircrew and battlespace managers involved in forming an accurate picture of the battlespace. If UCAS were to be extensively used, NEC would form a crucial part of the enabling capability. NEC, with all its facets included, allows commanders and operators to gain situational awareness, which the author contends, is the most important part of the kill-chain, enabling all other parts of the F2T2EA cycle to be conducted. While aircraft and sensor performance are crucial to the effectiveness of any counter-air system, situational awareness facilitates their use; its importance cannot be overstated.

An example of the stresses of air combat, and the factor that this can have on situational awareness, is the number of times during the Vietnam War US fighters were lost due to running out of fuel. For example, on one engagement between four F-4Cs and four MiGs, one F-4 crew was forced to eject when they ran out of fuel, due, it seems, to a total lack of awareness of the type of AAR available. During the same mission, the F-4s failed to shoot down any MiGs, despite being in a position of advantage. The F-4s had a total of 24 AAM

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[646] Stillion, *Blunding the Talons: The Impact of Peace Operations Deployments on USAF Fighter Crew Combat Skills,* Chap 6, pp.84-85

[647] See J. Y. Grau, *Human Consequences of Agile Aircraft: Psychological Consequences and Pilot "Situational Wareness" Survey,* Neuilly-Sur-Seine-Cedex: North Atlantic Treaty Organization - Research and Technology Organization, 2000. Chap 3, p.8.

[648] Lynn Carroll, 'Desperately Seeking SA', *TAC Attack*, March, 1992, p.6.

between them; none were used; instead 1200 bullets were expended, with no hits.[649] Ultimately, SA is basically a function of the aircrew flying and operating their aircraft and systems, with the ability to combine strands of information into a coherent air picture of what is taking place around them, often in a highly dynamic situation. It is a skill that is hard to gain, and maintain.

Barry Watts, in *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects,* believes future fighter against fighter encounters are likely to rely on superior weaponry.[650] What about the aircrew? Aircrew and other personnel are, currently, part of the situational awareness chain in air warfare. This may presently be necessary, particularly in situations that require speed of decision making that is not always based on linear events, that is, the 'fog of war', which may be best used to describe resistance, or friction, to plans. Ultimately, can gaining total situational awareness reduce this resistance to such a level that it does not affect campaigns? Watts considers that, 'driving one's own friction to zero while, simultaneously, rendering the enemy's effectively infinite is not, at its core, a technical problem'.[651] Watts believes that the greater the stress, the more data will be ignored, and the greater will be the confusion.[652] This rationale has merit - there is only so much that any human being can absorb, digest, and act upon in a given period of time; however, technology should allow friction to be less of a factor by not relying on human capabilities, which are generally not consistent, and are certainly vulnerable to the stresses that high intensity air combat scenarios generate.[653]

<u>Historical Analysis of Situational Awareness</u>

Prior to the 1991 Gulf War, for all the apparent progress in RF AAM technology, only the IR AAM had much success in combat.[654] Why was this? Was technology not the panacea that technologists and military tacticians envisaged? What role does modern technology play in gaining situational awareness, and therefore an advantage in gaining control of the

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649 See - John S. Attinello (ed), *Air-to-Air Encounters in Southeast Asia: Volume III: Events from 1 March 1967 to 1 August 1967 and Miscellaneous Events*, Arglington, VA: Institute for Defense Analyses Systems Evaluation Division, 1969, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADC003629&Location=U2&doc=GetTRDoc.pdf, (accessed 24 July 2012), Event III-291, pp. 345-346.

650 Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects,* p.45.

651 Barry D. Watts, 'Doctrine, Technology and War: Air and Space Power Journal Doctrinal Symposium', *Air & Space Power Journal*, 1996, http://www.airpower.maxwell.af.mil/airchronicles/cc/watts.html, (accessed 23 October 2009), Part 5: Implications for the Future.

652 *ibid.*

653 Robert Shaw, himself an ex-fighter pilot, describes the stresses faced, and the attributes required, of the modern fighter pilot – see Shaw, *op. cit.,* pp.xii-xiii.

654 See analysis at Appendices B and C.

air? Reviewing evidence from historical and test data on air-to-air engagements can aid analysis of what the vital elements of gaining control of the air are. It can be argued that the absence of situational awareness has been the cause of the majority of losses in actual air-to-air combat. Neither the introduction of advanced fighters, equipped with air intercept radars, nor the development of AAM have changed the fact that many air-to-air kills have been achieved without the targeted aircrew knowing the enemy was targeting them. Watts' analysis of historical combat data and anecdotal evidence from World War II to the Vietnam War, suggests that lack of situational awareness has been fundamental in approximately 80% of kills.[655] Watts' analysis is extraordinary. His main findings are that situational awareness has played a far more important role in air combat than having a technological advantage.[656] Is this correct? Watts' analysis is examined, with the aim of confirming its relevance.

Watts' analysis starts with the experience of a number of World War II pilots. For example, Lieutenant Colonel Mark Hubbard USAAF, a P-38 Lightening pilot, stated that in his experience during World War II, 'A wing man should always stay with his leader. Under no circumstances should there be less than two airplanes working together…and 90% of all fighters shot down never saw the guy who hit them'.[657] This was emphasised by another USAAF pilot, Colonel Hubert Zemke, who stated: 'Remember few pilots are shot down by enemies they see'.[658] Similarly, the German Me-109 pilot Erich Hartmann, one of Germany's most successful fighter pilots during World War II, said that: 'Today I am sure that eighty per cent of my kills never knew I was there before I opened fire…one factor always worked for me more than any other. I found I could spot enemy planes long before my comrades-sometimes minutes before them'.[659] 'The pilot who sees the other first already has half the victory'.[660]

Were the successes of Hubbard, Zemke and Hartman, down to superior flying skills, or was it having superior situational awareness? During World War II, training and experience played a significant part in the success of US and allied air forces. The superior performance of US fighters against German adversaries with similar equipment is believed to be due to the great advantage in basic and operational training which US fighter pilots

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[655] See generally, Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*, pp.45-55.

[656] *ibid.,* p.47.

[657] Lt Col Mark E. Hubbard USAAF, *The Long Reach: Deep Fighter Escort Tactics - VIII Air Force*, Major General W. E. Kepner (ed), AF HQ CO: Reproduction Platoon, 901st Engineer 1944, p.10.

[658] Colonel Hubert Zemke USAAF, *The Long Reach: Deep Fighter Escort Tactics,* p.33.

[659] Raymond F. Toliver and Trevor J. Constable, *The Blond Knight of Germany: A Biography of Erich Hartmann*, Blue Ridge Summit, PA: McGraw Hill Inc., 1970, p.173.

[660] *ibid.*

enjoyed. Less skilled German pilots led to higher combat losses, which further increased the pressure to produce large numbers of progressively less skilled pilots, resulting in a devastating downward spiral in pilot quality.[661] By early 1944, US fighter pilots had, on average, twice as much flight training as their German counterparts and over three times as much training in air-to-air combat and other operational skills.[662] There is little doubt that training was certainly a factor during World War II. Warden emphasises this in *The Air Campaign,* when referring to the huge losses the *Luftwaffe* suffered on the Eastern Front.[663] He also believes that: 'If it has not been practiced in peace, losses are likely to be high and the plan is unlikely to go as expected'.[664]

Watts' examples of air-to-air engagements between US and opposing Vietnamese forces using Russian built fighters, in Southeast Asia from 1971 through 1973, offers further evidence that situational awareness plays a major part in air combat. His views are based on a 1974 report from the USAF Tactical Fighter Weapons Center, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis – Part 1: Tactics, Command & Control and Training.*[665] This report was a follow on from the initial USAF evaluation of air-to-air encounters during the period of 1965 through to 1968 of the Vietnam War.[666] These reports collated and analysed data from all air-to-air engagements in Southeast Asia from 1 April 1965 to January 1968. Volume I identified and reconstructed 78 air-to-air encounters.[667] Volume II covered 151 engagements.[668] Volume III completed the study with 346 engagements.[669] Volume IV analysed these engagements, offering recommendations, with the aim of enhancing US air-to-air combat effectiveness.[670]

[661] See Maj Walker M. Mahurin USAAF,*The Long Reach: Deep Fighter Escort Tactics*, p.25.

[662] See Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933 -1945*, Baltimore, MD: The Nautical and Aviation Publishing Company of America, 1983, pp.240 and 262.

[663] Warden III USAF, *op. cit*., p.139.

[664] *ibid.*

[665] See generally, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis.*

[666] See William Sayers, 'The Red Baron Reports: What They Really Said', *Air Power History* 52, no. 3, 2005, pp.4-13. See also, Watts, *Six Decades of Guided Munitions and Battle Networks*, p.46.

[667] John S. Attinello (ed), *Air-to-Air Encounters in Southeast Asia: Volume I: Account of F-4 and F-8 Events Prior to 1 March 1967,* Arlington, VA: Institute for Defense Analyses Systems Evaluation Division, 1967, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADC003627&Location=U2&doc=GetTRDoc.pdf, (accessed 24 July 2012), pp.17-18.

[668] John S. Attinello (ed), *Air-to-Air Encounters in Southeast Asia: Volume II: F-105 Events Prior to 1 March 1967,* Arlington, VA: Instittute for Defense Analyses Systems Evaluation Division, 1968, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADC003628&Location=U2&doc=GetTRDoc.pdf, (accessed 24 July 2012), pp.17-19.

[669] Attinello, *Air-to-Air Encounters in Southeast Asia: Volume III,* pp.15-20.

[670] Attinello*, Air-to-Air Encounters in Southeast Asia: Volume IV: Analyses.*

The *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis* emphasises the vulnerability of fighters lacking situational awareness, concluding that: 'The most important factor affecting the loss of both MiGs and US aircraft as the element of surprise. The absence of attack warning was a serious handicap to both sides'.[671] The report states that: 'Of the [US] 37 total losses, 30 (81 percent) were judged to have received inadequate real-time warning. The remaining 19 percent (seven losses) were induced by fuel starvation when US aircraft continued to engage below safe separation fuel levels'.[672] Significantly, the report states that 35% of all US losses received no attack warning at all, and while the remaining 65% received some warning: '…the absence of real-time threat positioning did not enable US aircrews to acquire the threat in time to perform effective defensive actions'.[673] From this analysis, it is apparent that the lack of situational awareness played a part in 100% of US losses, to some extent. North Vietnamese MiG losses were also analysed, with 42% (31 of 75) not manoeuvring before being shot down; in addition, 14 other MiGs were shot down in undetected attacks as they positioned to engage other US aircraft, giving a total of 60% (45) which were destroyed in surprise attacks.[674]

The US experience prior to 1971 offers additional statistics on the importance of SA. Burton, in his brief *Letting Combat Results Shape the Next Air-to-Air Missile,* observes that from 1965 to 1968, of the 117 air-to-air kills achieved by US forces, 44 – 80% of the enemy were unaware of being targeted, while between 1971 and 1973, of the 73 kills claimed, between 60-80% were unaware.[675] Burton's brief comes with no references; however, the author's own reading of, *Air-to-Air Encounters in Southeast Asia: Volume IV: Analyses*, offers more granularity for engagements from 1965 to 1968. The absence of situational awareness was a factor on virtually all occasions when US aircraft were shot down. One of the main conclusions of the analysis observes:

> The analysis of the attack phase demonstrated that enemy success in achieving a position to fire was almost entirely dependent upon the ability to maneuver into a rear quadrant attacking position <u>before detection</u>. Conversely, whenever U.S. aircrews acquired the enemy aircraft <u>before</u> the attack maneuver was completed, U.S. aircraft negated the maneuver 95 percent of the time. The requirement for real time information on the position of enemy aircraft is apparent from these two results.[676]

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[671] USAF Tactical Fighter Weapons Center, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis,* p.61.

[672] *ibid.,* p.59.

[673] *ibid.,* p.60.

[674] *ibid.*, p.61.

[675] See Burton, *op. cit*., slide 6.

[676] USAF Tactical Fighter Weapons Center, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis*, p.124.

The fact that crews were able to negate the MiGs 95% of the time (that is, on only 5% of engagements did the MiGs achieve a shoot down, if seen by US crews first), means that if they had not had situational awareness of their presence, they would have suffered far more losses. In approximately 50% of cases, crews were not aware of enemy MiGs until less than 2 nm.[677] The report emphasises the significance of firing first: 'The importance of firing first can be seen in that for 209 encounters studied, in only four cases did an aircraft attacked first by another aircraft manage to destroy the attacking aircraft'.[678] This meant that most MiG attacks from the stern were successful: 'When the enemy attained a rear quadrant position <u>before detection</u>, the enemy fired first approximately 90 percent of the time'.[679] Although US crews had a kill ratio of 9:1 in scenarios where they possessed situational awareness, ultimately, if they had possessed better situational awareness, they would have suffered far fewer losses, and shot down more MiGs. Conversely, it was noted that if North Vietnam had been able to use their Ground Control Intercept radar control more effectively, and had weapons parity, far more US losses would have occurred.[680] In addition to the lack of SA leading to US losses, during the period April 1965 to August 1967, US crews were forced to terminate engagements on 160 occasions. On 51 of these, 32%, this was due to losing contact with the MiGs, either radar or visual.[681] This is an extraordinary number, clearly illustrating that the lack of SA can not only lead to being shot down, but also affect a mission's success, by allowing an adversary freedom of manoeuvre.

While not quite correlating with *Red Baron's* deductions, Burton's figures do support the conclusion that SA, or the lack of it, played a significant part in losses. This lack of situational awareness, which resulted in the relatively poor, and unexpected, kill ratio during the Vietnam War of approximately 2.5 to 1, was indicative of a number of causes, including poor training, restrictive ROE, and an expected technological advantage that did not in fact

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[677] *ibid.,* p.39.

[678] *ibid.,* p.45.

[679] *ibid.*

[680] *ibid.,* pp.54-56. At the time of the report, the US had a 9:1 attack effectiveness against MiG-21 fighters (if situational awareness of the enemy was obtained first), but it was estimated this would fall to 1:1, if MiGs achieved the rear quadrant 100 percent of the time, with the MiGs enjoying an advantage of 2:1, if weapon parity was achieved as well – see *ibid.*, figure III-B5, p.54.

[681] *Ibid.,* pp.103-104.

exist.[682] Even before the end of the Vietnam War, US analyses had identified enemy position and direction information, and long-range positive identification, as two of the main causal factors in poor US performance in air-to-air combat operations; the others were, 'Weapon versatility and reliability. Target discrimination against ground return. Aircraft rearward visibility. Man/machine compatibility'.[683] The overarching lesson from this period was that situational awareness is not easily gained; training, technology and experience is essential to the development of this vital skill.[684] Watts concludes that this relationship with World War II and Southeast Asia regarding situational awareness is significant.[685]

Post-Vietnam statistics also offer evidence of the criticality of SA. Some analysis comes from US simulations of air combat, conducted on instrumented ranges and in flight simulators. Although not actual combat flying, these tests, such as the Air Combat Evaluation (ACEVAL) and the AMRAAM AIM-120 Operational Utility Evaluation (OUE) were designed to gather statistics on engagement results.[686] ACEVAL was conducted using an Air Combat Manoeuvring Instrumentation (ACMI) range, which relayed information from all the aircraft involved to a ground monitoring system.[687] Since then ACMI systems have been extensively used by the US and European air forces for decades, greatly enhancing training opportunities.[688] The friendly force consisted of F-15 or F-14 fighters armed with AAG, AIM-9L IR AAM, and AIM-7F Sparrow semi-active AAM; the opposing

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682 See Hallion, *op. cit*., p.16. Statistics vary as to the number of US kills and losses. See, for example, Benjamin F. Schemmer, 'USAF's Crews Train to Win in Tac's Air Combat Program', *Armed Forces Journal International,* May 1974, pp.24-40, for details of 184 US kills, against 75 losses. Burton details 190 kills - see Burton, *op. cit.,* slide 3. See also, Survivability/Vulnerability Branch Methodology & Analysis Group, Air Force Dynamics Laboratory, 'A Comparative Analysis of USAF Fixed-Wing Aircraft Losses in Southeast Asia Conflict', Wright-Patterson Air Force Base, Dayton, OH: Air Force Systems Command, 1976, http://www.dtic.mil/dtic/tr/fulltext/u2/c016682.pdf, (accessed 24 July 2012), Table A-1, pp.78-83, which details 66 USAF fixed-wing combat losses to MiGs. See also, Graig C. Hannah, *Striving for Air Superiority: The Tactical Air Command in Vietnam*, College Station: Texas A&M University Press, 2002, p.3., Table 5: Fixed-Wing Aircraft In-Flight Combat Losses for All of Southeast Asia, January, 1962-January, 1973, which details losses of USAF – 66, USN – 12 and USMC – 1, giving a total of 79.

683 See, USAF Tactical Fighter Weapons Center, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis*, pp.1-2.

684 Marshall Michel describes the evolution of training exercises, such as the US Navy's Top Gun, and the USAF's Red Flag, as a direct result of the poor performance of US aircrews in Vietnam; see Marshall L. Michel, *The Revolt of the Majors: How the Air Force Changed after Vietnam,* Auburn University, 2006, pp.97-100, and 203-206.

685 Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*. p.50.

686 Dr Michael Venturino, William Hamilton, and Stephen R. Dvorchak, 'Performance-Based Measures of Merit for Tactical Situation Awareness', in *Aerospace Medical Panel Symposium*, Copenhagen: NATO Advisory Group for Aerospace Research and Development, 1989, p.4.2.

687 Clarence Robinson, 'Fighter, Missile Gains Pressed', *Aviation Week and Space Technology*, 4 April 1977, p.12. For a description of ACMI, see Anthony Thornborough, *Modern Fighter Aircraft: Technology and Tactics*,Sparkford: Patrick Stephens Ltd, 1995, pp.12-14.

688 ACMI ranges have been superseded by the Rangeless Airborne Instrumented Debriefing System (RAIDS). RAIDS gives the same information as ACMI, but is not confined by geographic boundaries - see Sqn Ldr Matt Nicholas RAF, 'Aircrew Leadership: Exercise CQWI', in *25 Years of Air Defence: Tornado F3,* Wg Cdr Justin Reuter RAF (ed), Arbroath: Squadron Prints Ltd, 2011, p.119.

force flew F-5Es, simulating, to a degree, the Soviet MiG-21 in performance, with AIM-9L Sidewinder and an AAG.[689] Watts observes that from the results of this trial, it was demonstrated that '…human factors dominated results 83-84 percent of the time'.[690]

The author's own survey of counter-air aircrew asked the question, 'How often were you required to enter the visual merge to kill an adversary, during Large Force Employment (LFE)/COMAO training sorties?' Seventy-eight percent were required to on less than10% of the time, with the remaining required to on 20% or less occasions. Why is this relevant? The responders to the question have on average 2000-3000 hours counter-air experience; many have flown hundreds of these types of training sorties. Almost 80% were able to kill their adversaries on >90% of occasions, without having to conduct visual air combat, with 100% having to on 20%, or less.[691] These statistics are similar to World War II, Vietnam, and the ACEVAL trials. The lack of adequate situational awareness appears to be a fairly constant metric in losses in counter-air warfare, approximately in 80% of engagements.

In 2005, the F-22 Raptor completed its initial operational test and evaluation (IOT&E). Similar to the AMRAAM OUE and ACEVAL, this trial included scenarios conducted in simulators and on an ACMI range. Open source official reporting indicates that the Raptor was able to dominate opposing fighters for the vast majority of the time, even when outnumbered. Major General Mark Welsh, the USAF's director of global power programmes, speaking to reporters in 2005, stated that the, 'Pilots in [the] IOT&E—most drawn from the F-15C community—raved about it being a huge leap over the time-tested Eagle'.[692] An official F-22 Programme Office brief to the media in 2007 stated that:

> Successful IOT&E results released in Feb 2005 = "Overwhelmingly Effective" performance…F-22s demonstrated exceptional performance during joint training exercise "Northern Edge 2006" in Alaska during June. Air dominance was ensured, improved situational awareness of all aircraft greatly enhanced the success of combat commanders.[693]

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[689] Robinson, 'Fighter, Missile Gains Pressed', p.12.

[690] Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*, p.50. Watts analyses the AMRAAM OUE, which was conducted in simulators and flown by operational aircrews during the early 1980s, observing that the results tended to confirm the provenance of the ACEVAL. Watts' sources, however, cannot be substantiated. These observations, therefore, are not used by the author. Watts' analysis is largely based on a presentations given by the Veda Corporation, and S. R. Dvorchak – see *ibid.,* pp.51-52.

[691] These crews possessed situational awareness of where these adversaries were. See appendix H.

[692] John A. Tirpak, 'The F/A-22, in Fire and Flak', *Air Force Magazine* 88, no. 2, 2005, p.33.

[693] See, US Pacific Air Force, 'F-22 Program Facts', (2007). http://www.pacaf.af.mil/shared/media/document/AFD-070207-060.pdf, (accessed 29 October 2012).

These views seem to indicate that the F-22 (and these types of aircraft) will achieve control of the air without entering the visual arena.[694] However, these results need to be examined in context – should everything said by the US military be believed? On the basis that we cannot know for sure, a judgement needs to be made on the likelihood that the Raptor is as good as it is ‘officially’ stated to be. For the purposes of this thesis, the author is sufficiently satisfied that the Raptor is likely to be an extremely capable air superiority fighter, not least, because the US has proven to be adept at producing world-beating air combat systems.

The Raptor’s stealth and speed, when aligned with appropriate tactics, and advanced avionics, sensors and sensor fusion, apparently allowed the Raptor pilots to kill adversaries without being detected. The required situational awareness would have been garnered through NEC, combining data fusion - using gateways, such as BACN and the US Tactical Information Broadcast System (TIBS), a Ultra High Frequency line-of-sight or satellite-interactive network. The TIBS network provides secure near-real-time, multi-sensor, multi-source situational awareness and threat warnings. BACN is an airborne communications relay and gateway that is part of the US DoD’s Objective Gateway programme, which is developing advanced gateway capabilities allowing real-time information interactions between different TDL systems.[695] The F-22’s apparent dominance in the IOT&E reiterates that situational awareness most often determines the outcome of the counter-air battle, especially when technology is harnessed to augment situational awareness.[696] These results were achieved by the F-22s operating as a single fighting force, unable to transmit their own situational awareness via NEC means. Currently, stealth aircraft are not equipped with conventional TDL, such as Link-16, and cannot communicate with other aircraft types, as this can be detected by electronic sensors – instead they use an Intra-Flight Data Link (IFDL), designed to relay data and synchronised air picture only amongst the Raptors. A new programme to provide secure TDL for the F-22 and other stealth aircraft is being developed. Objective Gateways, such as BACN, should help solve this problem.[697]

[694] For example, according to Maj. Gen. Richard B.H. Lewis, US Air Force executive officer for the F-22 programme (in 2006), the F-22’s capabilities, with its speed and manoeuvrability, are unprecedented. During Exercise Northern Edge 2006 in Alaska in early June, the F-22 proved its mettle against as many as 40 adversaries during simulated battles. The F-22 achieved a 108-to-zero kill ratio - see Staff Sgt. C. Todd Lopez, 'F-22 Excels at Establishing Air Dominance', *The Official Web Site of the U.S. Air Force* 2006, http://www.af.mil/news/story.asp?storyID=123022371, (accessed 9 September 2009).

[695] For a description of TIBS and BACN, see US Department of Defense, 'RDT&E Budget Item Justification: Link 16 Support and Sustainment', 2007, http://www.dtic.mil/descriptivesum/Y2008/AirForce/0207434F.pdf, (accessed 14 May 2009), p.12. See also, *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047*, p.27.

[696] Watt, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects,* p.54.

[697] See, for example, T.E. Bell, 'WB-57: NASA's Eyes on High', *Combat Aircraft*, May 2010, p.37.

Can the human factor input to situational awareness be considered crucial, or can technology allow the required level of situational awareness to be used by an autonomous/highly-automated system? Computer programs exist which are capable of interpreting the information available, that is, the situational awareness, making decisions for the operator and the mission commander; there are few apparent reasons why aircraft systems could not react as required using these programs. An example is SOAR software, which is a cognitive architecture program, giving both a view of what cognition is and an implementation of that view through a program for AI. Since its beginnings in 1983, it has been widely used by AI researchers to model different aspects of human behavior.[698] Glen Taylor and others, describe the benefits of SOAR in a paper, *The Future of C2 Enabling Battlefield Visualization: An Agent-based Information Management Approach.* This paper identifies the requirements of a system for enabling battlefield visualisation through automating the information management process.[699] SOAR based simulations have been trialed; for example, all aircraft flown in a USAF synthetic operational training exercise, conducted over 48-hours, were controlled by SOAR based SI software.[700]

Trials with UCAS have been conducted under simulation by the US, UK and others, to determine the levels of autonomy to which these systems can operate.[701] These systems require a high level of situational awareness. The more autonomous a system is required to be, the higher the level of situational awareness necessary. It is planned that software programs will allow for automatic responses by UCAS to real-world (simulated at the moment) conditions, for example, reacting to being targeted by SAM, or AAM.[702]

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698 University of Michigan, 'What is Soar', 2010, http://sitemaker.umich.edu/soar/home, (accessed 19 August 2011).

699 G. Taylor, S. Wood, and K. Knudsen, 'Enabling Battlefield Visualization: An Agent-Based Information Management Approach', in *10th International Command and Control Research and Technology Symposium: The Future of C2*, Ann Arbour: SOARTEC, 2005.

700 TACAIR-SOAR AI software used over 5200 rules, which were based on 'expert' input. For example, see Randolp Jones and others, 'Automated Intelligent Pilots for Combat Flight Simulation', *AI Magazine* 20, no. 1, 1999, Figure 2, p.30, and Figure 3, p.31 – both these flow-diagrams illustrate how a BVR engagement could be conducted. See also, Paolo Gunetti, Haydn Thompson, and Tony Dodd, 'Simulation of a Soar-Based Autonomous Mission Management System for Unmanned Aircraft', *Journal of Aerospace Information Systems* 10, no. 2, 2013, pp.53-70.

701 The National Archives, 'DE&S - Strategic Unmanned Air Vechicles (Experiment) Integrated Project Team', 2007, http://webarchive.nationalarchives.gov.uk/+/http:/www.mod.uk/defenceinternet/microsite/des/ourteams/air/strategicunmannedairvehiclesexperimentintegratedprojectteam.htm, (accessed 3 September 2009).

702 An example of this is a system that can rapidly re-plan a mission in flight, using intelligence updates and other relevant information. The Dynamic Airborne Mission Management (DAMM) system is being developed by the UK MOD – see R. M. Taylor, 'C2-MM Collaboration Teamwork Models and Metrics', Portsdown West: Defence Science and Technology Laboratory, 2010, http://www.dsto.defence.gov.au/attachments/Taylor%20-%20TTCP%20DHS%20Taylor%2030.pdf, (accessed 21 October 2011).

Lack of situational awareness in the battlespace has historically been a major factor in which side wins. Watts, in *Doctrine, Technology and War,* states that some US strategists and scientists:

> ….have begun to grapple with the prospective changes in war fighting that lie ahead, [and] begun to argue that future advances in surveillance and information technologies will sufficiently lift 'the fog of war' to enable future commanders to 'see and understand everything on a battlefield.' Advances in sensor technologies and information systems should enable the side exploiting them more effectively to eliminate its 'fog of war' while turning the opponent's into a 'wall of ignorance.[703]

The removal of this 'fog of war' has been an ambition of military strategists for centuries. In 1995, US Admiral William Owens advocated the doctrine 'Dominant Battlefield Awareness'. This doctrine proposes connecting existing sensors and personnel together via information and command-and-control systems, making it possible to detect, track, and classify most, if not all, of the relevant entities on land, sea, and air or in space.[704] Current programmes, particularly in the US, are pushing the boundaries of this principle. BACN, a data-fusion engine already mentioned, is an exemplar of the vision that the US military has with regard to merging all entities and sensors into one fused system.[705] Simply put, Watts and Owens are stating that situational awareness is, and will be, the critical factor in warfare. Unless targets can be found and tracked, then all the precision weapon technology available will be of little use.

Air-to-Air Missile Development

The weapons effectors required for future counter-air systems are open to discussion. Current means of destroying adversary aircraft invariably use AAM and AAG. Evaluating the effectiveness of current AAM systems requires an understanding of AAM development and current doctrine; this allows the potential incorporation of air-to-air weapons onto UCAS to be evaluated, and to establish what killing or negating systems will be required in the 2040 battlespace. Prior to the advent of AAM, fighters were generally armed with guns or cannons that fired forward along the aircraft's longitudinal axis. From 1914 to the early 1950s, air-to-air combat was led by the use of the AAG. Military forces continually sought to improve aircraft manoeuvrability and engine performance to give pilots manoeuvre advantages which they could exploit to achieve effective firing positions. Without AAM that could reliably target aircraft from significantly greater ranges than those at which AAG were

[703] Watts, 'Doctrine, Technology and War: Air and Space Power Journal Doctrinal Symposium', p.101

[704] Admiral William A. Owens, 'The Emerging U.S. System-of-Systems', in *Strategic Forum, National Defense University, Number 63*, February 1996, http://www.ndu.edu/inss/strforum/SF_63/forum63.html, (accessed 17 June 2010).

[705] See RDT&E Budget Item Justification: Link 16 Support and Sustainment, *op. cit*., p.12.

effective, there was little alternative, whenever the target could not be taken unawares, but to fall back on air combat manoeuvring skills and aircraft performance to reach the close-in firing positions required.[706] This also applied to early versions of IR AAM, which were only effective in the stern sector of enemy aircraft.[707]

There were limitations and frustrations with the development of early AAM. The Germans had developed prototype AAM towards the end of World War II. The Ruhrstahl X-4 was designed to provide German fighters with a standoff weapon that could be used to attack allied bombers from outside the reach of the bombers' defensive armament. The X-4 was an air-to-air rocket-powered, wire-controlled missile, which was guided with a joystick; it had a maximum range of over three miles.[708] Although the X-4 was not used in combat, its acquisition by the US after the war offered an indication of future AAM possibilities. Since the Soviets had also gained access to German technology and scientists in 1945, with the onset of the Cold War there was an obvious incentive for the US to develop effective AAM before the Russians did.[709] The UK, Israel and France were also involved in developing AAM during this period, and developed a number of effective AAM types. However, it is the US and Russia that are the world leaders in AAM development and doctrine, with Israel, France and the UK close behind. China is playing catch-up, with a combination of Russian AAM in its inventory, a number of its own programmes, the capacity to reverse engineer almost anything, and a seemingly easy route to gaining technology from the US and others; it is possible that there will come a point in the future when China reaches parity with the West.[710]

Western AAM Development

The first US AAM appeared in the mid-1950s, when the US Air Force declared its air-intercept missile (AIM), the AIM-4 Falcon, operational in 1955.[711] That same year, the first

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[706] For an excellent history of the development of the AAG, see Shaw, *op. cit*., pp.1-5.

[707] *Ibid*., pp.36-37.

[708] Heinz Nowarra, *German Guided Missiles*, Atglen, PA: Schiffer Publishing Ltd, 1993, pp.12-13.

[709] US efforts under Operation Lusty, and Project Overcast, succeeded in 'sequestering' the rump of German technology, and scientists, ahead of the Soviets – see, Wolfgang W. E. Samuel, *American Raiders*, Jackson: University Press of Mississippi, 2004, pp.x, 4, and 160.

[710] For example, during the 1990s, the US approved the sale of more than $15 billion worth of strategically sensitive equipment to China, which could be used to facilitate the development and production of nuclear weapons, radars, *inter alia* - see 'U.S. Exports to China 1988-1998: Fueling Proliferation', 1999, http://www.wisconsinproject.org/pubs/reports/1999/execsumm.html, (accessed 25 November 2012). See also, Tai Ming Cheung (ed), *New Perspective on Assessing the Chinese Defence Economy*, San Diego: The University of California Institute on Global Conflict and Cooperation, 2011, p.19.

[711] Andreas Parsch, 'Hughes AIM-4 Falcon', *Directory of U.S. Military Rockets and Missiles*, 24 July 2008, http://www.designation-systems.net/dusrm/m-4.html, (accessed 14 March 2011).

production model of the IR AIM-9 Sidewinder AAM became operational, and the RF AIM-7 Sparrow I, which was a beam-riding RF AAM, slaved to an optical sight, entered service.[712]

Despite the AIM-9 Sidewinder's simplicity and maintainability, the missile has limited range. While a substantial advance over the AAG for air-to-air combat, early versions of Sidewinder were still a close-in weapon, its effectiveness limited to within-visual-range engagements and in clear air outside of clouds. Although the Sidewinder has some utility at night, if target acquisition can be achieved by the fighter's radar, for most night or all-weather engagements, particularly at distances BVR, early variants of the Sidewinder offered little capability. Early AIM-9 IR AAM, which relied on detecting the exhaust heat plume from a jet engine, were designed for use against non-manoeuvring targets, attacking from the rear aspect of the defending aircraft. During the Vietnam War, North Vietnamese MiG fighters countered the AIM-9 by turning in towards the attacking fighter, negating the heat source at the rear of the aircraft.[713] Post-Vietnam, the US developed the all-aspect, highly manoeuvrable AIM-9L IR AAM. The AIM-9L entered service in the US in 1978 and in Europe in 1982, when UK Harriers were equipped with AIM-9L AAM for the Falkland's conflict. Twenty-six AIM-9L were fired, achieving 19 kills, giving a P_k of 0.73.[714] This appears a vast improvement, but does need to be kept in context; Argentinean aircraft were not equipped with flares to counter these IR AAM. Also, many AIM-9L shots were taken from the stern, unseen by the Argentinean aircrews, again emphasising the importance of situational awareness.[715]

By the mid-1980s many nations had developed and deployed IR decoy flares in response to emerging IR AAM lethality. To mitigate this, the USAF developed an improved AIM-9, the AIM-9M. This was an AIM-9L with improved flare rejection technology designed to counter decoy flares.[716] The USAF, USN and USMC fired 48 AIM-9M during the Gulf War of 1991, achieving only 11 kills. The AIM-9 P_k was reduced to just 0.23 - much closer to Vietnam era performance than the 1982 Falkland's War.[717] The US AIM-9X, UK ASRAAM, the French MICA and Israeli Python 4 and 5 AAM, are all examples of IR AAM developed with the main emphasis being counter-measures and manoeuvrability, including a HOBS

[712] For AIM-9 development background and capabilities, see Hewson, *op. cit*., pp.42-51. For AIM-7 Sparrow development background and capabilities, see *ibid*., pp.97-99.

[713] See Shaw, *op, cit*., p.129, for defensive manoeuvring considerations against rear-sector IR AAM.

[714] Ethell and Price, *op. cit*., p.215. The importance of AAM kill probability is examined in Chapter 5.

[715] Ethell and Price, *op. cit*., p.215.

[716] Hewson, *op. cit*., p.43.

[717] Stillion and Perdue, *op. cit.*, PPF.27.

function.[718] The high design lethality of late generation IR WVR AAM is in a large part due to the their ability to sustain very high load factors during the endgame manoeuvre (the phase at which an AAM may have to manoeuvre to hit an aircraft which is manoeuvring itself, in self-defence), precisely the scenario in which most AAM fail to kill their targets.[719] Although mainly employed in the visual arena, modern IR AAM can be employed BVR, particularly in the head-sector, at ranges outside the visual acuity of most aircrew, and at night, when even with the use of Night Vision Systems, aircrew cannot acquire targets easily.[720] When utilised with TDL, IR AAM can be launched without an acquisition, flying through cloud, achieving target positioning from on- and off-board systems (third-party targeting).[721] However, the true BVR realm belongs to the RF AAM, which are usually much larger, with a corresponding greater range, and possessing their own radar seeker-head.

During the Cold War the USAF had a requirement to engage high and fast bombers necessitating a high AAM P_k. This resulted in the fielding of a nuclear-tipped version of the Falcon, the AIM-26A/GAR-11, which had radar-proximity fusing and utilised semi-active radar homing, giving it an all-weather capability.[722] No AIM-26A were used in anger, and while offering a significant capability, presented problems with collateral damage, particularly against low-level overland targets. Conventional radar-guided AAM for air-to-air combat with sufficient range to be launched BVR, entered the inventory in the early 1960s when the initial US Navy variants of the F-4 Phantom II, equipped with the AIM-7 Sparrow AAM and the AN/APQ-72 radar, became operational. By the Yom Kippur War in October 1973, the Israeli Air Force also had F-4s equipped with AIM-7 AAM.[723]

The requirement to engage targets at ranges from a CSG that mitigated any weapon delivery systems that an adversary might have, emphasised the need for the US Navy to acquire an AAM with the ability to engage aircraft at very long-range. The AIM-54 Phoenix was the first operational radar-guided AAM that could be launched in multiple numbers

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[718] See Hewson, *op. cit*., for development and capabilities – ASRAAM, pp.39-41., MICA, pp.58-61, Python 4 and 5, pp.24-27, and AIM-9, pp.42-51.

[719] For considerations on defeating AAM, including manoeuvring, see Erik Berglund, *Technologies for Future Precision Strike Missile Systems: Mission Planning Technology,* Neuilly-Sur-Seine Cedex: North Atlantic Treaty Organization, 2001, p.1.4.

[720] For a review of the impact of NVG on human performance, particularly visual acuity and depth perception, see Avi Parush and others, 'The Human Factors of Night Vision Goggles', *Reviews of Human Factors and Ergonomics* Vol 7, no. 1, 2011, pp.238-242.

[721] ASRAAM is an example, see MBDA Missile Systems, 'ASRAAM', June 2011, http://www.mbda-systems.com/mediagallery/files/asraam_background-1367919209.pdf, (accessed 15 August 2012), p.1.

[722] Andreas Parsch, 'Hughes AIM-26', *Directory of U.S. Military Rockets and Missles*, 9 May 2007, http://www.designation-systems.net/dusrm/m-26.html, (accessed 27 May 2010).

[723] Nordeen, *op. cit*., p.111.

against different targets from an aircraft, making the Phoenix the US Navy's main air defence long-range weapon. The Phoenix was carried by the US Navy's F-14 Tomcat, which had the capability to launch as many as six AIM-54 missiles simultaneously in all weathers and heavy jamming environments.[724]

The late 1980s and early 1990s saw the development of a new generation of RF AAM. The AIM-120A AMRAAM was introduced at the end of the Cold War to provide a 'fire and forget' active radar guided weapon with data-link support provided by the radar on the launch aircraft, allowing multiple simultaneous shots. Until the advent of the AIM-120, the use of semi-active AAM still required the launching fighter to continue towards the target, using its on-board radar to guide the AAM until impact. This would mean both aircraft getting within a few miles of each other at missile impact.[725] If the adversary aircraft was also equipped with AAM, a race against each other ensued, with each fighter crew vying to increase any advantage they may have; each crew would be attempting to achieve the best standoff range - ($R_{seperation}$).[726] Although an important part of counter-air engagements, $R_{seperation}$ is matched by the importance of AAS to counter EA techniques.[727]

The introduction of the AIM-120 AMRAAM sought to give the advantage back to US fighter crews. AMRAAM employs active radar target tracking and active RF target detection to provide an autonomous launch, rendering a capability against single and multiple targets in all environments. However, early AMRAAM variants suffered from a lack of robust capability in an EW environment. The AIM-120A was followed by the improved B-model, and then by the AIM-120C. Versions of the AIM-120C are currently the backbone of the US and its allies. Open sources indicate improvements in AIM-120 capabilities.[728] The latest version, the AIM-120D introduces a redesigned seeker, which is a conformal antenna, probably of AESA design, a two way data-link, GPS to supplement inertial guidance, improved kinematics, and better seeker performance against HOBS targets.[729] Combat statistics for the Aim-120 variants to date are not robust, amounting to ten kills (including a friendly fire incident against a UH-60 Black Hawk helicopter) of which six were genuine BVR shots, for the expenditure of 17 AIM-120 AAM – giving a P_k of 0.59.[730]

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[724] *ibid*., pp.100-102.

[725] *ibid.,* p.33.

[726] $R_{seperation}$ is also known as F-Pole – see Shaw, *op. cit*., pp.51-52.

[727] EW techniques can be used to generate false targets on radar receivers, both aircraft and AAM based; see US Air Force Doctrine Center, *op. cit.,* p.11.

[728] For a detailed background on AMRAAM development and capabilities, see Hewson, *op. cit.,* pp.102-108.

[729]See *ibid*., p.103, and also David A. Fulghum, 'Cyber, Kinetic War Collide', *Aviation Week and Space Technology*, 1 October 2007,. p.27.

[730] Stillion and Perdue, *op. cit.,* PPF.20.

Significantly, no target was equipped with a modern defensive EW capability, and, therefore was not representative of the type of air-to-air system likely to be used against US and other Western forces in a modern peer-on-peer BVR engagement. In addition, AMRAAM class missiles lack the extended range that may be required when pitted against Su-35 Flanker type aircraft, equipped with ramjet propelled AAM, now being developed in Russia and Europe.[731] A European consortium is developing the Meteor AAM which will use advanced air breathing motor technology. Conventional rocket motor powered AAM rely upon an initial boost phase to achieve the high speed required, followed by a 'coast' phase to intercept the target. Latest generation, highly manoeuvrable aircraft, are able to out run and out-manoeuvre conventional missiles at the extremes of their range. The air breathing Ramjet motor used by Meteor provides sustained power, following the initial boost that offers extended maximum ranges, and no-escape zones, over AIM-120.[732] The advantage of ramjet BVR AAM lays in their ability to sustain thrust and turning performance in the endgame phase of an engagement, where conventional solid rocket AAM fly on inertia alone for much of their flight, and rapidly lose speed when turning.[733]

Russian and Chinese AAM Development

Until the 1980s, Soviet AAM technology lagged the West in rocket propellants, airframe and guidance designs. That changed with the deployment of the RF Vympel R-27 (NATO reporting name AA-10 Alamo) and IR Vympel R-73 (NATO reporting name AA-11 Archer) AAM during the 1980s.[734] In kinematic terms, the IR R-73 series, and the BVR R-27 and R-77 (RVV-AE) (NATO reporting name AA-12 Adder) are highly competitive against their Western equivalents, and the long-burn variants of the R-27 outperform all Western solid propellant competitors.[735] The next step for Vympel is the production of the air breathing ramjet RVV-AE-PD design, displayed since the 1990s at numerous trade shows.[736]

Russian seeker technology has made great advances since the early 1990s, largely as a result of the availability of digital signal processing chips available on the world market. The Russian weapons company Agat, which manufactures semi-active and active radar seekers for the AA-10 and AA-12 AAM, has openly acknowledged its use of Western digital

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[731] For a description of Su-35 capabilities, see Jackson, *op. cit*., pp.512-513.

[732] For Meteor development and capabilities, see Hewson, *op. cit.,* pp.65-72. See also, MBDA Missile Systems, 'Meteor', March 2013, http://www.mbda-systems.com/mediagallery/files/meteor_background-1367919554.pdf, (accessed 9 April 2013).

[733] Hewson, *op. cit*., pp.68-69.

[734] For AA-10 development background and capabilities, see *ibid*., pp.79-82. For AA-11 background and capabilities, see *ibid*., pp.32-35.

[735] *ibid.,* pp.86-90.

[736] *ibid.,* pp.91.

signal processing chips in a variant of its seeker-head.[737] The move away from analogue and early digital seekers to software programmable digital seekers is significant, since it opens up many choices in signal processing and counter-countermeasure techniques hitherto only used by US, EU and Israeli manufacturers. In practical terms, there is no reason why a later model digital variant of the AA-10 and AA-12 would be no less difficult to defeat by jamming than Western equivalent active seekers. With modern seeker technology, AAM can be updated with new software fixes relatively quickly. Replacement modes can be kept secure until combat operations commence. According to Kopp, '…no side would have an advantage; in effect the advantage in the rapid adaptation of ECM held by the West during the Cold War period is largely nullified'.[738] This is a significant observation.

The Russian philosophy has been to make fighters that can carry an exceptional payload of AAM. Up to 14 AA-12s can be carried on the Su-35 Flanker. It is envisaged that the Su-35 will also be able to carry up to five long-range missiles. Labelled 'very-long-range' air-to-air missile, the K-100-1 (*Izdeliye* 172S and 172S-1) has been developed from the earlier K-172 AAM. The *Izdeliye* has a range of 160-215 nm, and is capable of reaching speeds up to 2,160 knots (approximately Mach 3.0-4.0) to engage targets flying at altitudes ranging from 10 ft. to 100,000 ft.[739] This type of AAM is a significant threat to HVAA such as AWACS and AAR aircraft. The AA-11 IR AAM continues to evolve. Russian industry is working on a Focal Plane Array seeker for their future WVR missiles, to compete against the ASRAAM, AIM-9X, and Python-5 seekers, adding further IR counter-countermeasures capabilities. Details of a Russian passive X-band RF anti-radiation seeker are classified, but is a unique capability in the AA-10 and AA-12 AAM.[740] It seems Russia may be reaching parity with the West in AAM technology, and may well be exceeding this capability.

China is making significant progress in the development of AAM technology. The PLAAF operates a diverse mix of indigenously manufactured and imported Russian AAM. Imported Russian AA-10, AA-11 and AA-12 AAM are primarily used with the imported Russian built Su-27SK and Su-30MKK Flankers, and the home-grown copy of the Flanker, the J-11. Indigenous Chinese built AAM are dominant across the Chinese built fleets of J-10A/S Sinocanard, J-11B Sino-Flanker, J-8 Finback, J-7 Fishbed, J-6 Farmer, A-5/Q-5 Fantan, and JH-7 Flying Leopard.[741] Currently, China manufactures only two BVR guided

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[737] See Dr Carlo Kopp, 'The Russian Philosophy of Beyond Visual Range Air Combat', 25 March 2008, http://www.ausairpower.net/APA-Rus-BVR-AAM.html, (accessed 19 April 2009), pp.9-10.

[738] *ibid.*, p.10.

[739] See Hewson, *op. cit*., pp.76-77.

[740] See *ibid*., pp.79-82, for AA-10 development, and pp.86-90, for AA-12 background.

[741] See *ibid*., pp.512-513

AAM, the active radar guided PL-12/SD-10 'Sino-AMRAAM' and the reverse engineered semi-active radar guided Selenia Aspide Mk.1, designated the PL-11.[742] China also has a much more diverse inventory of IR AAM in its inventory. These include the PL-5 to 9 series, which are derivatives of a range of Western AAM, such as the AIM-9 and Rafael Python AAM.[743]

What is the significance of Western, Russian and Chinese AAM development? The sheer diversity of AAM types in service or being introduced into US, Russian, EU, Israeli and Chinese inventories, and the prospect of evolving regional clone variants and derivatives, presents a genuine long-term problem in intelligence gathering, analysis and countermeasures. If all major nations have similarly effective AAM in the coming decades, unless there is a radical change in advantage for one nation against another, the employment of AAM may be deemed the least effective means of destroying or deterring an adversary. Should this be the case, then a radical reappraisal of Western BVR doctrine and tactics is required. Most US and European fighter aircraft just do not currently have the capability to carry a payload of more than six BVR AAM, without compromising range and endurance, unlike Russian and Chinese fighters, with the Flanker, and its variants, capable of carrying a payload of 10 -14 BVR AAM.[744] The P_k of AAM systems is, and will continue to be, a major issue requiring research and understanding. Whether future systems carry a payload of AAM will largely depend on whether other means of disabling adversary counter-air air-breathing systems will be necessary. Chapter 5 examines the evolution of air-to-air warfare, specifically analysing AAM/AAS effectiveness.

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[742] Roger Cliff and others, *Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century*, Santa Monica, CA: RAND Corporation, 2011, Chap 10, pp. 218-222. See also, Hewson, *op. cit*., pp.54-58 for PL-11/12 capabilities. For capabilities of Chinese produced fighters, see Jackson, *op cit*., pp.97-102, 129-132 and 141.

[743] See *ibid.,* pp. 5-13 for specification of PL-series of IR AAM.

[744] See Jackson, *op. cit.,* p.513.

Chapter 5: The Evolution of Air-to-Air Warfare

'The farther backward you can look the farther forward you are likely to see'

Winston Churchill [745]

Will future air-to-air combat follow the norms that previous major conflicts have witnessed? It is possible that future peer-on-peer combat will result in more intense air battles, compared with those seen since the Vietnam War, Middle East and Falkland's conflicts, with all sides potentially experiencing high attrition rates.[746] The requirement for an appropriate air dominance system compels assessment. Before this can be done, it is important to understand how AAS have performed in the past. Evaluating statistical trends in historic air-to-air combat allows for a methodical approach in analysing the effectiveness of the types of weapon systems which were used, and those which may be required in the future. Addressing the question of how often more lethal or effective weaponry determines tactical outcomes requires the examination of statistical data. The best evidence comes from the domain of air-to-air combat. There is a large amount of data available from both actual and simulated air combat.

AAM are the primary weapons in air-to-air combat, and have been since the beginning of the Vietnam War. The employment of AAM has not been without difficulties and controversies, however. An understanding of the history and P_k of AAM is crucial before any evaluation of future systems can be conducted. The P_k achievable of any AAM depends on a number of factors, including its kinematic performance, especially during the endgame phase of flight (the ability to react to and guide to a target during the last seconds of an AAM flight), against the intended target, and the performance of its seeker-head and fusing subsystems, predominantly in an EW countermeasures environment.[747] Understanding the capabilities and constraints of AAM is absolutely central to the whole process of the development of air platforms, sensors, weapons, and the tactical doctrine employed. While it is important to have a thorough understanding of the principles of AAM P_k, however, AAM are but one part of a system required in achieving a kill. The AAS includes the launch aircraft and aircrew operating it, the sensors required to detect and track adversary aircraft, including NEC, the EW systems, and all other personnel and assets involved in supporting the operation. The USAF, for example, when assessing AAM

[745] National Churchill Museum, 'Quotes', http://www.nationalchurchillmuseum.org/wit-wisdom-quotes.html, (accessed 29 July 2012).

[746] See analysis of air-to-air kills since 1965 at Appendices B-D.

[747] Shaw, *op. cit.,* pp.57-58.

effectiveness during the Vietnam War, defined a fighter weapon system, as containing the major sub-systems of , '…the airframe, propulsion, and controls; avionics; weapons and fire control; the human being (pilot and crew)'.[748] AAM form the basis from which all current counter-air doctrine and tactics are formed. A thorough understanding of not only one's own capability is essential, but also that of potential adversaries. The overall capability of the AAS is consequently used when assessing overall P_k.

Air-to-Air System Kill Probability

Frequently misunderstood, or indeed, little understood by some air power proponents, is the likelihood of an AAM actually achieving a kill.[749] To recap, AAM P_k affects the choice of how many AAM need to be fired in order to kill an adversary aircraft. In addition, this in turn, affects almost every other consideration, such as the number of AAM carried on a fighter aircraft, affecting the required size of that fighter, and/or the number of fighters required to counter potential adversaries. The basis on which the formula for AAM P_k is founded, is the ratio of AAM to P_k – this is referred to as the probability of a single shot kill (P_{ssk}).[750] How this is calculated depend on a number of factors, but will essentially be constructed on a series of AAM live-firing trials against the full gamut of target profiles, and simulated firings, which are conducted in a Hardware-in-the-Loop facility, which is a ground-based test, using actual aircraft and missile sensors and the EA techniques which would be used against them.[751] These are normally centred on the ability of the AAS to operate in the full range of conditions likely to be encountered during an air battle. A number of factors affect AAS P_k: Adversary EA capabilities; target manoeuvre; the serviceability of the AAS; the performance/capability of the AAS – including own aircraft air sensor and third-party sensor effectiveness; the skill of the aircrew, and situational awareness. An acceptable AAS P_k in the most difficult scenario is an extremely important part of a counter-air system. If aircraft are limited in the number of BVR AAM carried, then AAM P_k needs to increase.

There comes a point with AAM P_k, when firing more than one AAM in a salvo does not increase the P_k significantly. As the P_k of a single AAM increases, the corresponding

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[748] See, Attinello, *Air-to-Air Encounters in Southeast Asia: Volume IV: Analyses,* p.107.

[749] For example, in an otherwise exceptional reference guide for the planning of counter-air operations, The US *Joint Publication 3-01* only mentions probability of a kill once, and then only in relation to attacking fixed C2 sites – see, US Joint Chiefs of Staff, *op. cit*., p.IV-5.

[750] See Robert E. Ball, *The Fundamentals of Aircraft Combat Survivability Analysis and Design*, Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 2003, pp.2-5.

[751] Mitchell Sisle and Edward McCarthy, 'Hardware-in-the-Loop Simulation for an Active Missile', *Simulation* 39, no. 159, 1982, pp.159-167.

increase in AAM P_k with the number of AAM fired, decreases, relatively. The numbers of AAM fired in a salvo will therefore depend on the known P_{ssk} of the AAM in a particular scenario.[752] There is no panacea for this – it will depend on a number of factors, including the type of conflict – COIN, policing, or interstate war. These will alter the risks which politicians and military leaders are prepared to take, whether that is losing aircrew and/or aircraft, or the assets that the fighters are protecting, and, not least, the repercussions if the battle is lost. The point at which the P_{ssk} of an AAM makes it worthwhile to have a one-shot doctrine is, therefore, subjective.[753] With a P_{ssk} of 0.5, two AAM are required to be fired in salvo in order to achieve a P_k of 0.75 - if that is the desired P_k. If the AAM P_{ssk} were as low as 0.15, then even launching eight AAM in a salvo would only achieve a P_k of 0.728. For the purposes of this thesis, it is the author's view that in high intensity state-on-state warfare, against a peer adversary, the outcome of which is deemed critical, an AAS P_k of greater than 0.9 is required – when applied to a salvo of AAM. Even this may not be enough, if an adversary has similar AAS P_k, and greater numbers of AAM and aircraft.

When considering firing a number of AAM in salvo in order to increase P_k, it is difficult to predict if each AAM will encounter the same conditions. Therefore, the actual P_k may be somewhat different from that calculated on paper. It is, nonetheless, a crucial factor when deciding AAM load-out, salvo numbers and tactics.[754] Russian and Chinese air power tacticians understand the issue of AAM P_k, and have adopted procurement strategy and doctrinal tactics to counter this challenge. The Russian exemplar of BVR combat has its origins in the Cold War, when Soviet operational analysis identified that the low P_k of AAM seekers and airframes, especially if degraded by countermeasures, would have a significant impact on effectiveness. By the 1970s the standard Soviet technique in BVR tactics was to launch a salvo of two AAM.[755] It is not unreasonable to expect Sukhoi Flankers to launch three or four round BVR AAM salvos during the opening phases of an engagement. The aircraft being targeted have a difficult problem as it must jam, decoy and/or out manoeuvre three or four tightly spaced inbound missiles. Even with P_{ssk} of 40%, a three round salvo has a P_k of approximately 0.8. If neither side has a decisive advantage in EW capability, the Flanker does have a decisive advantage in aircraft and AAM kinematics, in addition to having up to 6-7 times the payload of BVR AAM to expend, when compared to the current proposed load-out of 2 internally carried AMRAAM AAM for the F-

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[752] Robert E. Ball, *The Fundamentals of Aircraft Combat Survivability Analysis and Design*, Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 2003, pp.2-5.

[753] AAM P_k formula and the effects that AAM salvos have are explained at Appendix A.

[754] For examples of exchange ratios and the effect of firing AAM in salvos, see Howard Van Horn, 'Can Simple Models Predict Air Combat Results?', *Journal Of Aircraft* 48, no. 2, 2011, pp.652-659.

[755] Kopp, 'The Russian Philosophy of Beyond Visual Range Air Combat', *op.cit.*

35 JSF.[756] The introduction into service of the Russian PAK-FA and Chinese J-20 stealth fighters in the coming decades, will only add to their capabilities.

Unless possessing exceptional AAS P_k, and superior numbers, any air force not having parity in aircraft and AAM load-out should avoid BVR combat.[757] Significantly, the Chinese appear to be mirroring Russian doctrine, and BVR AAM capability. This has implications for any future counter-air system. An important trend in the PLAAF's modernisation is the development and deployment of support aircraft serving as force multipliers to enhance the effectiveness of its combat aircraft. These support aircraft include AAR, AEW, AWACS, and EW and ISR.[758] An example of the determination of the PLAAF to adopt Western doctrine is the 2011 deployment of J-10 fighters to Kazakhstan, where they participated in a Shanghai Co-operation Organisation (SCO) COMAO exercise.[759]

Historical Analysis of Air-to-Air Kills

That a given capability is technically feasible does not necessarily mean that it is operationally useful in an actual combat scenario.[760] Since the advent of BVR AAM, approximately 660 air-to-air kills have been recorded by Western equipped BVR AAM-equipped forces. 105 of 663 (15.8%) kills have been with RF AAM, of which only 26 of 663 (3.9%) have been BVR.[761] During the Vietnam War, US fighter crews conducted approximately 600 air-to-air engagements in Southeast Asia from 1965 to 1973, achieving 190 kills against 75 losses.[762] RF AAM were very seldom used successfully in air combat,

[756] Robert Johnson, 'The F-35 Straps on Its Missiles for the First Time Ever', *Business Insider: Military & Defense*, 2012, http://articles.businessinsider.com/2012-02-21/news/31081646_1_f-35-smart-bombs-weapons, (accessed 25 February 2012).

[757] Kopp, 'The Russian Philosophy of Beyond Visual Range Air Combat', *op. cit.*

[758] SinoDefence, 'Air Forces', *SinoDefence.com*, 2011, http://www.sinodefence.com/airforce/default.asp, (accessed 16 Decembe 2011).

[759] Peter Foster, 'China Air Force to Unveil New Aerobatic Team', *The Telegraph*, 2011, http://www.telegraph.co.uk/news/worldnews/asia/china/8730876/China-air-force-to-unveil-new-aerobatics-teams.html, (accessed 21 November 2011).

[760] For example, during the early years of the Vietnam War, air combat training on instrumented ranges revealed that approximately 50% of simulated AAM shots were being taken out of parameters. Furthermore, from 17 June 1965 to 17 September 1968, approximately 600 AAM were fired during 360 air-to-air engagements against Vietnamese fighter aircraft, achieving a probability of a kill of approximately 10% - see Frank W. Ault, 'Report of the Air-to-Air Missile System Capability Review', Naval Air Systems Command, 1969, http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA955142, (accessed 19 November 2012), Section I.A, p.2., and Section V.B, part 6, p.35.

[761] See analysis at Appendices B and C.

[762] Burton, *op. cit*., slide 3.

either by US aircrews in Southeast Asia during 1965-1973, or by Israeli aircrews in the conflicts of 1973 (Yom Kippur) and 1982 (Bekaa Valley).[763]

An example of AAM P_k (in this case, a probability of a hit), are figures used for pre-combat AAM P_k used by the US during the Vietnam War. The calculations took into account four causal factors: the probability of successful launch; the missile was fired within a successful envelope; the missile tracked the target, and the missile actually hitting the target. The probability of the 'system' working is the sum of these factors.[764] The RF AIM-7E had a pre-combat P_k of 0.71, while the IR AIM-9B was 0.65.[765] During the period from April 1965 to 1 August 1967, however, the actual combat results were somewhat different, with the AIM-7E being 0.15, and the AIM-9B, 0.25.[766] As previously discussed, when P_k is so low, if it cannot be improved, then launching AAM in salvos can offer a solution.

US RF AAM actual demonstrated P_k during the Vietnam War, from 1965-1973 was 0.06 (55 of 918).[767] US fighters were required to use the gun on North Vietnamese Russian MiG fighters, almost 100 times more than originally expected.[768] The Yom Kippur War of October 1973 was a much shorter conflict, but the air-to-air combat was intense. Burton in, *Letting Combat Results Shape the Next Air-to-Air Missile,* states that despite the large number of engagements, with 261 kills claimed, Israeli F-4 Phantoms only fired 12 AIM-7 AAM, claiming 5 kills (1.9%); with one a single BVR kill (0.4%).[769] Israel's June 1982 invasion of Lebanon offers a similar example. By 1982, the Israelis had F-16 and AIM-7-equipped F-15s in their inventory. During the major air battles between Israeli and Syrian fighters that occurred over the Bekaa Valley in Syria in June 1982, the Israeli Air Force split air superiority responsibilities between their F-15s and F-16s, the latter being armed only with an internal gun and short-range IR AIM 9-L AAM. The Israelis are thought to have shot down 82 Syrian fighters.[770] Twenty-three AIM-7 AAM were launched, achieving 12 kills (14.6%), giving a P_k of .52, with only a single BVR kill (1.2%) from 5 shots (.20 P_k) .[771]

From March 1965 to the end of US air operations against North Vietnam in January 1973, only two BVR kills were officially recorded out of a total of 918 reported attempts at

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[763] Burton's analysis has only 1 BVR RF AAM kill in each of the 1973 and 1982 Israeli conflicts (1% and 4% respectively) - see Burton, *op. cit*., slides 4-5.

[764] Attinello, *Air-to-Air Encounters in Southeast Asia: Volume IV: Analyses*, p.92.

[765] *ibid.,* p.98.

[766] *ibid.,* p.93.

[767] See Appendix C.

[768] Stillion and Perdue, *op. cit.,* PPF.19.

[769] Burton, *op. cit.,* slide 3.

[770] Grant, 'The Bekaa Valley War', p.61.

[771] Burton, *op. cit.,* slide 5.

launching RF AAM used.[772] From 1965 to 1982, approximately 95 of 953 (10%) of US and Israeli RF AAM firings occurred at distances beyond five nautical miles.[773] From these only four achieved kills (0.04 P_k).[774] Attempts to achieve BVR firings by US and Israeli aircrews during these conflicts were few, and are indicative of the problems inherent in the early evolution of BVR combat. Prior to the 1991 Gulf War, only 4 of 614 (0.65%) kills achieved were BVR. Since 1991, 22 of 49 (45%) of kills achieved have been BVR.[775] Statistically, this appears an exceptional increase, with the proportion of BVR kills increasing 69 fold. However, how applicable is this? Since the 1991 Gulf War, with US and allied forces enforcing a No-Fly-Zone over Iraq, and during the 1999 Kosovo campaign, AIM-120 AAM has demonstrated an overall 0.59 P_k in combat to date, with 17 AMRAAM fired for 10 kills.[776] Thirteen AMRAAM have been fired to achieve six BVR kills, giving a BVR P_k of 0.46.[777] Significantly, the Iraqi MiGs shot down were fleeing and non-manoeuvring; also of note, Serbian J-21 Jastreb aircraft shot down during the Kosovo conflict had no radar or ECM, and the MiG-29 Fulcrums shot down had inoperative radars. In addition, there are no reports of ECM used by any fighter, and no fighter had comparable BVR weapons. All engagements involved numerical parity or superiority.[778] Although a significant achievement for forces operating at great distances from their own bases, and proving the efficacy of AWACS and other assets, the fact that the opposition was relatively inept and incapable of posing any real threat needs to be acknowledged. This is absolutely essential when analysing the actual effectiveness of counter-air systems involved. Will these conditions apply to a peer adversary, such as China?

Why was the exploitation of the technical capability to launch BVR RF AAM prior to the advent of the AIM-120 so rare? Why were there not considerably more BVR shots and kills? The reluctance of US and Israeli fighter crews to risk BVR shots in actual combat during the Vietnam War and Middle East conflicts was not only due to ROE issues, but also, an initial mistrust of the effectiveness of RF AAM. Fighter aircrew were reluctant to shoot BVR unless they could be highly confident that the target was the enemy. This reluctance to risk air-to-air fratricide, known as 'Blue-on-Blue' within the counter-air community, was often reinforced by rigorous ROE.[779] Burton observed that, 'The most

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[772] See *ibid.*, slides 3 and 5. Burton states that 10% of RF AAM firing attempts were BVR.

[773] *ibid*., slide 5.

[774] *ibid.,* slide 3. See Appendices B - D for details of air-to-air engagements from 1965 to the present.

[775] See analysis at Appendix B.

[776] Stillion and Perdue, *op. cit.,* PPF.20.

[777] *ibid.,* PPF.25.

[778] *ibid.*

[779] Watts, 'Doctrine, Technology and War: Air and Space Power Journal Doctrinal Symposium', Chap 4: Doctrine and Technology.

dominant aspect of missile air combat to date [1985] has been the requirement to positively identify the target. Results in dogfights [were] almost all shots within visual range and from the rear hemisphere'.[780] As a result, BVR AAM kills were only practicable when the ROE criteria were fulfilled by the use of special equipment, such as Identification, Friend or Foe (IFF) interrogators.[781]

Burton's analysis of US engagements during the Vietnam War established that of 92 RF AAM launched BVR by US pilots, only 2 kills were achieved, an abysmal 1.84% success rate.[782] These results would naturally lead to crews wishing to delay AAM launch; however, both the RF and IR AAM used up to the end of 1967 were not particularly effective in the closer, more manoeuvrable engagements either. Analysis from *Project CHECO,* emphasised the extremely poor effectiveness of the AAM used at the time, particularly the AIM-7:

> .…35 percent of the AIM-7s and 26 percent of the AIM-9s were considered launched outside permissible parameters…There were only 11.1 percent recorded hits, with 2.8 percent designated probables, of the AIM-7…For the slightly more effective AIM-9, there were 18.6 percent hits recorded, of which 1.7 percent were probable. These statistics indicate that the maneuvering environment of air-to-air combat presents many problems to the fighter pilot who is dependent upon the missile as his only weapon.[783]

North Vietnamese statistics were no better. Although they possessed the Alkali RF AAM, only five firings were witnessed by US aircrews, with no hits.[784] The Atoll IR AAM, which was similar to the AIM-9B Sidewinder, was the preferred weapon, achieving 24 kills from 209 launched, giving a P_k of 0.11.[785] The dominant limitations, however, were perhaps not technical, but a matter of aircrew preference. Although this analysis highlights the poor AAM performance of both Soviet built and US AAM, it is worth noting that US aircrew would launch missiles early, outside of valid parameters, in order to distract MiG pilots:

> The most effective escort-counter to a close-in attack was found to be a hard turn to point at or slightly in front of the MiG, followed by early launch of an AIM-7/9. Under these conditions the escort aircraft normally did not have time to achieve a radar lock-on or to satisfy valid launch parameters; the AIM-7/9 was launched primarily to disrupt the MiG's attack. Despite the absence of effective missile guidance, these early firings were frequently the escort's only

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780 See Burton, *op. cit*., slide 12.

781 Watts, 'Doctrine, Technology and War: Air and Space Power Journal Doctrinal Symposium', Chap 4.

782 Burton, *op. cit.,* slide 5.

783 Lt Charles H. Heffron USAF (ed), *Project - Contemporary Historical Evaluation of Combat Operations Report: Air-to-Air Encounters over North Vietnam: 1 January - 30 June 1967*, San Francisco: HQ PACAF, Directorate, Tactical Evaluation, 1967. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA485407, (accessed 26 July 2012), p.45.

784 USAF Tactical Fighter Weapons Center, *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis*, p.25.

785 *ibid.,* p.24.

> chance of diverting the MiG's attention and causing it to abort its attack on the strike elements…[786]

Examples of fratricide in modern air warfare are fortunately few; however, the 2003 Gulf War saw an RAF Tornado GR-4 and a USMC F-18C shot down by US Patriot SAM.[787] During the 1982 Falkland's War, an Argentinian Mirage II suffered damage by an AIM 9-L AAM fired from a RN Sea Harrier; subsequently, Lt Garcia Cuerva's Mirage was shot down by his own side while attempting to make an emergency landing at Port Stanley Airfield.[788] Missiles of all types, air-to-air, surface-to-air, and air-to-surface, have grown ever more reliable and lethal, yet military operators must still make quick shoot/no-shoot decisions in order to be effective, and, under the extraordinary pressures of combat environments, those decisions remain open to fatal error. The tragic downing of two US Blackhawk helicopters by two US F-15Cs in the no-fly zone (NFZ) over northern Iraq in 1994, which resulted in the deaths of all 26 people on board, graphically demonstrates the difficulties of reliably identifying adversaries in air-to-air engagements, and this was not in contested airspace.[789] It is essential for military forces to be able to identify friends from adversaries; technological advances should enable significant improvements in gaining this situational awareness.[790] The potential for fratricide remains a characteristic of modern air warfare. Advances in sensors and information systems ought to deliver improved methods of identifying adversaries; already examined, JTIDS is an example.

Analysis of air-to-air kills in the modern era show a definite trend towards the use of AAM, in particular, BVR RF AAM. It was not until the Gulf War of 1991 that the synergy of equipment, including by this time E-3A AWACS aircraft, and operational circumstances permitted a significant portion of the engagements resulting in 16 BVR AAM kills, from a total of 35 (46%).[791] Sixty-seven RF AAM were fired, 29 of which were launched BVR, achieving 22 kills (BVR P_k of 0.59; overall 0.32).[792] Prior to the Vietnam War, all air-to-air kills were achieved by the use of the AAG. The author has examined the majority of air-to-air kills achieved by US, UK, and Israeli forces from the Vietnam War to the present, but

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786 *ibid.,* p.41.

787 'Glaring Failures Caused US to Kill RAF Crew', *The Guardian*, 31 October 2006, http://www.guardian.co.uk/uk/2006/oct/31/military.iraq, (accessed 14 October 2011).

788 Ethell and Price, *op. cit.*, pp.61-67.

789 For a dissection of this incident, see generally, Scott A. Snook, *Friendly Fire: The Accidental Shootdown of U.S. Black Hawks over Northern Iraq*, Princeton, NJ: Princeton University Press, 2002.

790 Watts, 'Doctrine, Technology and War: Air and Space Power Journal Doctrinal Symposium', Chap 4.

791 See Air Force Historical Research Agency, 'USAF Aerial Victory Credits', 2010, http://www.afhra.af.mil/factsheets/factsheet.asp?id=11421, (accessed 18 April 2010). See also Robin Lee, Air-to-Air Victories in Desert Storm', *Vulture's Row*, 2010, http://www.rjlee.org/aakill.html, (accessed 12 October 2010).

792 Barry D. Watts and Dr Thomas A. Keany, *Gulf War Survey, Volume II, Operations & Effects and Effectiveness* 1993, http://www.airforcehistory.hq.af.mil/Publications/fulltext/gulf_war_air_power_survey-vol2.pdf, (accessed 4 March 2009), Part II, p.113.

has not included minor engagements, such as those that have occurred between Israel and Middle Eastern countries outside of major conflict, or those between the US and Libya during the 1980s, or between India and Pakistan in 1971. These and other engagements, including those during the Iran/Iraq conflict during the 1980s have not been examined, due to the difficulty in verifying the results. It is considered that these engagements do not unduly affect the overall statistical analysis. The information at Appendices B - D is taken from a number of sources, some of which differ slightly from each other. While not intended to be definitive, they are, nonetheless, consistent enough to allow statistical trends to be used and understood.

From the Vietnam War, beginning in 1965, to the 1982 Falkland's War and Bekaa Valley conflict, most air-to-air kills were achieved by IR AAM – 54.7%, with 33.4% by AAG. Only 11.9% of kills were from RF AAM, with a derisory 0.6% BVR. From 1991 to date, 65.3% (32 of 49) air-to-air kills have been from RF AAM, with 44.9% (22 of 49) of these BVR; 30.6% have been from IR AAM.[793] No kills have been by AAG, although, two kills were achieved by US A-10 Thunderbolt anti-tank aircraft with an air-to-ground gun; both of these kills were against slow moving helicopters.[794] Statistics sometimes deceive and confuse. However, the significance of the analysis is the establishment that air-to-air kills from AAG since 1991 have been zero. Further, none of the kills achieved from 1991 have involved classic visual air combat manoeuvring.[795]

There have been far fewer air-to-air engagements since 1991, than the period from 1965 through to 1982. There has been a rapid decline in state-on-state conflict since 1991, with intra-state conflict and insurgency being dominant. This does not mean that state-on-state conflicts will not occur in the future. Are Western states mentally prepared for conflicts that require control of the air to be achieved against peer or near-pear adversaries? The advent of AIM-120 AMRAAM has dramatically changed the way in which BVR air-to-air combat is conducted. Since 1992, all Western RF AAM kills have been achieved by the use of the AIM-120 AMRAAM. An overall P_k of 0.59 may seem impressive; however, this increase in P_k needs to be kept in perspective. The analysis illustrates the increase in the percentage of BVR kills, increasing from 0.6% prior to the 1991 Gulf War, to 43% in all major air-to-air engagements since. IR AAM kills have fallen from 55% to 28.5%.[796] However, statistically, the number of air-to-air engagements and AAM used does not offer compelling proof that

[793] See analysis at Appendices B – D.

[794] These A-10s were not fitted with any AAM – see Craig Brown, *Debrief - a Complete History of U.S. Aerial Engagements: 1981 to the Present*, Atglen, PA: Schiffer Military History, 2007, pp.116-118, and 136-142.

[795] See generally, Craig Brown, *op. cit.*

[796] See Appendices B – D.

AAM are the panacea for future air combat. There are a number of factors that have come together to enable this apparently dramatic increase in effectiveness of BVR AAM. Notwithstanding the AAS P_k already discussed, the evolution of air-to-air tactics has changed a great deal since the Vietnam War. The continuing development of AMRAAM class systems, and most importantly, the integration of NEC, allowing a significant improvement in situational awareness and BVR tactics, has helped achieve this transformation.

The biggest difference in weapon kills is the use of the AAG in air-to-air engagements, falling from 33% in the period up to the 1991 Gulf War, to 0% since.[797] This is significant when making any judgement on the procurement/integration of AAG into future counter-air platforms. It is the author's view that the efficacy of future AAG employment requires examination; indeed, whether the fitment of an AAG will be relevant at all. Though acknowledging that what has happened in the past, will not necessarily be the case in the future, trends do need to be analysed. While the statistical analysis of air-to-air kills cannot offer definitive guidance on procurement strategy, or tactical doctrine, the results should aid decisions on future platforms, sensors, doctrine, and tactics. The analysis conducted, in the author's opinion, has established that although BVR RF AAM use and P_k, and AAS $P_{k,}$ have greatly improved, it is insufficient to guarantee gaining control of the air in future conflicts. Unless AAM/AAS P_k is significantly improved, particularly in the EA environment, then other methods of negating adversaries will be required, particularly, when a peer adversary has dominance in numbers, in both aircraft and weapons.

Too few AMRAAM have been used in air-to-air scenarios to offer any meaningful statistical analysis. Without a near-peer, or peer adversary, with all the capabilities these will have, AMRAAM performance in the 'real world' can only be guessed at by using open sources. The author considers it axiomatic that unless AMRAAM, or any AAM, can operate in a complex EA/denial environment, then any NEC, and all other sensors, weapons and qualities of aircraft and aircrew will be severely tested.

Modern Air-to-Air Combat Philosophy

It is not normally possible to destroy an enemy's forces in one engagement – this applies in all domains, including the air. Even if this were possible, reserves would (or should) be in place, to fight another day.[798] Depending on the exchange ratio, and the number of reserves, the destruction of even a small percentage of an attacking force can have serious repercussions, especially if the war goes on for an extended period. Terms such as

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[797] *ibid*.

[798] For an interesting perspective on the importance of reserves, see Warden, *op. cit.,* pp.98-108.

decimation and annihilation are sometimes used to describe an engagement outcome. 'Decimate' means to 'kill one in ten'. 'Annihilate' means to kill more than 90% of a deployed force.[799] Even if a force is 'only' decimated, it would not take many similar outcomes before that force was effectively annihilated, rendering it completely ineffective. The 1982 Falkland's War took a massive toll of the Argentine Air Force. Of the 129 air combat aircraft available, approximately 47 were destroyed. This was not quite annihilation, but much more than decimation.[800] The Israeli Air Force essentially annihilated the Syrian Air Force in the Bekaa Valley in June 1982, for no losses in air-to-air engagements.[801]

The drive in BVR AAM development is to achieve a kill on an adversary aircraft as far from your own aircraft and forces as possible, before he can achieve a kill on you. The theory offers a number of advantages, including less danger to the shooter, allowing a greater separation range (F-Pole) between the shooter and the target at AAM impact.[802] There are problems with engaging adversaries at great ranges however. Already discussed, without robust means of identifying a target at range, incidents of fratricide may increase. The cost of developing fighters and sensors that are capable in the BVR environment is huge. In terms of kinematic performance, the impact of the launch aircraft's kinematics at the point of AAM launch is vital.[803] Ramjet AAM, such as Meteor, may offer a viable alternative, as these are not significantly affected by an increase in the launch fighter's speed and height.[804]

According to Stillion and Perdue, in *Air Combat, Past, Present and Future,* if a conflict develops between China and the US over Taiwan, it would be very difficult to predict who would have the advantage in the technological/countermeasure game. China could enjoy a 3:1 advantage in fighters, if the US could fly from Kadena Air Force Base in Japan, or approximately 10:1 if forced to operate from Andersen Air Force Base in Guam.[805] Historically, overcoming these odds requires huge qualitative superiority. Such qualitative superiority is extremely difficult to achieve against a comparable power. An example of this was Wold War II, which saw Germany pit its air force against a number of opponents; in all cases, until the summer of 1940, the Luftwaffe proved a formidable force, annihilating all

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799 Wg Cdr Cris Mills RAAF (Retd), 'Will the Us Air Force Be Annihilated in the Next War?', *Air Power Australia - NOTAM*, 2009, http://www.ausairpower.net/APA-NOTAM-170209-1.html, (accessed 23 May 2009).

800 *ibid.*

801 Grant, 'The Bekaa Valley War', p.61.

802 Shaw, *op. cit.,* pp.51-52.

803 Kopp, 'The Russian Philosophy of Beyond Visual Range Air Combat, *op. cit.*

804 Described to the author by Jonathan Aird, Chief Missile Engineer, MBDA Ltd; 24 November 2011, (KCL's Serendipity Rule).

805 Stillion and Perdue, *op. cit.,* PPF.31.

adversaries, until it came up against the RAF, in what became known as 'The Battle of Britain'.[806] The Battle of Britain was 'won' not only by British and Commonwealth forces, but with the aid of French, Czech, and Polish airmen.[807] This was a classic example of an air campaign waged at such distances from their own operating and support bases, that the Luftwaffe lost the battle.[808] The military/industrial complex played a significant part, allowing greater RAF fighter aircraft production, and more fighter pilots being trained when measured against Germany; this, aligned with the fact that those pilots that the Luftwaffe lost, were almost always for the duration of the war, made it unnecessary for much of the RAF's central and northern commands to be used.[809] Klaus Maier, in *Germany and the Second World War*, states: 'The German failure to achieve air supremacy and the unfavourable time of year reduced British fears of a landing. [The] war-economy considerations forced a disbanding of the deployment of Operation Sea-Lion…'.[810] Operation Sea Lion, the planned invasion of Britain, was effectively cancelled, when Hitler issued his Directive No 21 'Barbarossa', which turned the German military's attention towards Russia. Alexander Dallin, in *German Rule in Russia 1941 – 1945,* writes, 'Gone where the last illusions of downing Britain 'by one stroke', gone was the pretence of German-Soviet 'friendship cemented by blood''.[811]

Lack of control of the air by Germany over the airspace of northern France and southeast England, was one of the deciding factors in Britain avoiding an invasion. Any success of invasion depended on gaining air superiority over the area of operations.[812] Alexander Seversky certainly believed that Germany had no hope whatsoever of gaining air

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806 An early official review of the Battle of Britain was conducted by Cecil James from the RAF Air Historical Branch; *The Battle of Britain* offers a view of the air battle, formed almost immediately after the battle – see generally, T. C. G. James, *The Battle of Britain*, Sebastian Cox (ed), London: Frank Cass, 2000.

807 There were other nationalities, including Americans, Dutch, Belgians and Norwegians – see Narracott, *op. cit.,* p.43. The RAF in 1940 suffered from a serious shortage of combat ready pilots, as well as ground crews – see, Richard Overy, *The Battle of Britain: Myth and Reality*, London: Penguin Books, 2010, pp.38-39.

808 *Ibid.,* p.110.

809 See Richard Overy, *The Air War: 1939 - 1945*, Washington, DC: Potomac Book, Inc, 1980, pp.32-33. Most German losses were over the British mainland, the Channel, and the North Sea, with most survivors not able to be recovered – see *Horst Boog,* 'The Luftwaffe's Assault'*, in The Burning Blue: A New History of the Battle of Britain*, Paul Addison and Jeremy A. Crang (eds), London: Pimlico, 2000, pp.48-49.

810 Research Institute for Military History (ed), 'Germany's Initial Conquests in Europe', in *Germany and the Second World War*, vol. II, Oxford: Claredon Press, 1991, p.405.

811 Alexander Dallin, *German Rule in Russia: 1941 - 1945*, Second Edition, London: The MacMillan Press, 1981, p.15. For perhaps one of the most stirring descriptions of the German malaise following the Battle of Britain, see Francis K. Mason, *Battle over Britain*, London: McWhirter Twins Ltd, 1969, pp.482-483.

812 Stephen Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain*, London: Aurum Press, 2000, p.109. It is argued by Richard Overy that the Battle of Britain was not the crucial factor in the postponement of an invasion; other factors were, such as the German Navy and Army command's understanding that they would face significant, if not insurmountable, difficulties against the Royal Navy and Army – see generally, Overy, *The Battle of Britain: Myth and Reality*, in particular, pp.108-109.

superiority over the south of England. Seversky argued (in August 1940) that the Luftwaffe had inferior fighters, and their doctrine, which was based largely on supporting the army, with aircraft such as the Stuka, meant they were not geared to conduct successful counter-air operations against the RAF.[813] The fact that an actual invasion of Britain may not have been the main German objective does not alter the point that Germany underestimated the importance of gaining control of the air. The importance of 'winning' however, is made clear by Richard Overy: 'It is evident that not a lot was needed to deter Hitler from the idea of invading Britain. Fighter Command tipped the scales. The failure to destroy the Royal Air Force ruled out the possibility of a cheap, quick end to the war in the west and kept alive an armed anti-Axis presence in Europe'.[814]

Russian and Chinese fighter doctrine relies on a number of basic tenets, including: superior numbers and firepower; sensor diversity on aircraft and weapons; advanced EW, for example, DRFM cross-polarisation jammers conducting EA, and towed radar decoys, and, significantly, a greater ability to absorb attrition.[815] The West's lead in sensors and electronics is not nearly as substantial as in the past. Significantly, technologies developed for the computer, gaming, television, medical imaging, telescope, and wireless network industries can be directly applied to fighter sensors and weapon systems. The impressive Russian Su-27 Flanker (and its later variants) is unquestionably the aircraft which has caused Western experts most concern to date.[816] Of the West's fighters - the Swedish JAS-39 Grippen, the French Rafale, the Typhoon and the US F-22 Raptor - only the fifth-generation F-22 has thrust-vector control.[817] Russian developers believe that the key to dogfight supremacy will rest in their pilots' ability to engage enemy fighters in any position relative to their own aircraft. It is arguable whether this ability to out manoeuvre fighters is relevant in an era when long-range BVR AAM capability is of such importance, and the potency of HOBS AAM and HMCS which are coming into service.

It is not by accident, however, that all Western fighters strive for an ability to obtain an advantage in maximum sustained and instantaneous turn performance. These two attributes allow fighter aircraft to turn quicker, while maintaining energy, allowing weapons, such as IR AAM, to be used quickly. It is also crucial when attempting to get into the rear-hemisphere of an adversary's aircraft in order to employ the AAG. Currently, it is

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[813] See Seversky, *op. cit.,* pp.34-41. One does not have to agree with all that Seversky argues, but his views have some validity; he was, after all, proven correct.

[814] Overy, *The Battle of Britain: Myth and Reality*, p.110.

[815] The Belorussian 'Satellite' DRFM jammer, for example, can produce cross-pole jammimg – see, Belarus 558 Aircraft Repair Plant, '558 ARP Offers Satellite', *Take-Off,* November 2010, p.35.

[816] See Jackson, *op. cit.,* pp.512-513.

[817] *ibid.,* pp.788-792.

considered essential that any modern fighter must have the ability to manoeuvre to defend itself in the visual arena.[818] Furthermore, in a high intensity conflict, when faced with an adversary with capable aircraft, weapons, and highly trained aircrew, it is not always guaranteed that the BVR shoot-out will succeed. The introduction of extremely agile AAM, capable of being employed at very high off-boresight angles, HMCS, which enable a pilot to look at a target and shoot, have altered the way in which air-to-air combat is fought. If required to enter a visual merge, the requirement for an aircraft to 'turn and burn', as fighter aircrew say, is greatly diminished. Future requirements may differ, but do need considerable thought.

The Flanker has a large internal fuel capacity and load carrying capability.[819] All Flankers carry an IRSTS – existing US fighters do not. Significantly, AMRAAM launches have large, unique thermal signatures.[820] The Su-35BM Flanker will have the full panoply of sensors and electronic defences, including an IRSTS to detect the launch flare of the AIM-120, a Radar Warning System to sense radar and AAM active seekers, a MAWS to detect AAM, DRFM jammers to jam the AAM seeker-heads and the launch fighters' radars, a towed decoy, and the inherent ability to generate extremely high turn rates to out-manoeuvre incoming AAM.[821] The PAK-FA is likely to have even greater capabilities.[822]

Future Air-to-Air Scenario

The importance that AAS P_k plays in air-to-air combat has been highlighted in the RAND study, *Air Combat, Past, Present and Future*, hypothesising on a possible conflict scenario between the US and China over Taiwan.[823] This study offers a realistic scenario in which opposing US and PRC fighters are pitted against each other. It effectively illustrates the implications of fighter numbers and AAS P_k. Using this as an example, the author establishes a scenario of US F-22 Raptor versus PRC F-35 Flanker aircraft. Operating in formations of 24 aircraft, a Flanker regiment can employ 16 very long-range anti-HVAA AAM, 240 AA-12/PL-12 BVR AAM and 48 AA-11 WVR AAM, giving a total of 304 AAM.

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[818] For a view on the perceived importance of WVR air combat manoeuvring, see Flt Lt Kevin Terret, 'Stalemate: How the Future of Air Power Might Look in the Shadow of the Emerging Fifth-Generation Air Threat', *Air Power Review* 15, no. 2, Summer 2012, pp.18–32.

[819] Jackson, *op. cit.,* pp.512-513.

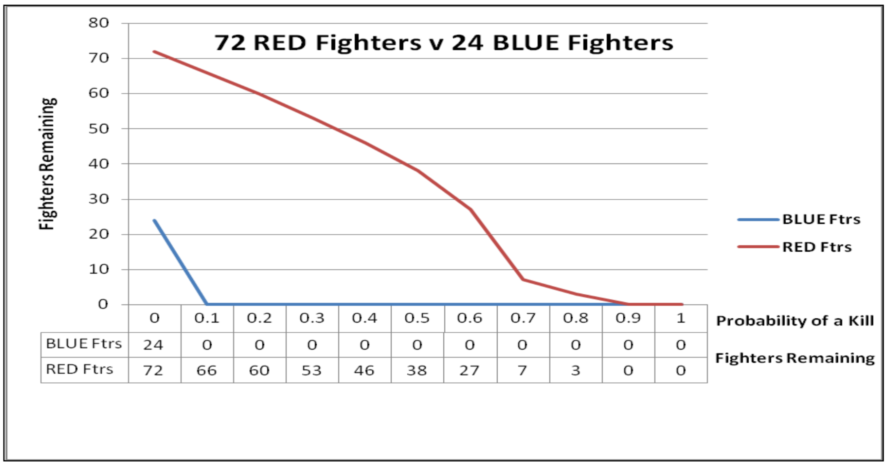
[820] Dr Carlo Kopp, 'Assessing Russian Fighter Technology', *Air Power Australia Analyses*, 26 June 2008, http://www.ausairpower.net/APA-2008-04.html, (accessed 8 May 2009).

[821] The ability for an aircraft to manoeuvre aggressively, just before an AAM arrives, can defeat the AAM's ability to follow, and achieve a fusing distance, see Shaw, *op. cit.,* pp.59-61.

[822] See Jackson, *op. cit*., pp.513-515. See also, Andrey Fomin, 'Generation 5: Russian Move - PAK FA Undergoing Tests', *Take-Off,* July 2010, pp.20-29.

[823] Stillion and Perdue, *op. cit.,* PPF.40-53.

Conversely, 24 F-22s can employ a total of 192 AAM: 144 AIM-120 AMRAAM and 48 AIM-9 IR AAM.[824] In the following scenario, Chinese forces are RED, while US forces are BLUE. In a possible air-to-air scenario, it is worth examining an air engagement where 72 RED fighters, encounter 24 BLUE fighters.[825] For the purpose of this analysis, the AAS P_k required is greater than .90 (in these examples the P_k is set at .93). Both sides launch their BVR AAM at the same time. Blue has 144 BVR AMRAAM. Red has 720 BVR PL-12 AAM and 48 HVAA AAM. Neither side enters within visual range of each other, therefore, their IR AAM are discounted. The table below details the outcome of an air battle, depending on the P_k of both the BLUE and RED force's AAS. Both RED and BLUE field the same aircraft, sensor and aircrew capabilities.



	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
BLUE Ftrs	24	0	0	0	0	0	0	0	0	0	0
RED Ftrs	72	66	60	53	46	38	27	7	3	0	0

Table 2: 72 RED versus 24 BLUE fighters: AAS kill probability versus fighters remaining

The example in Table 2 illustrates that with an AAS P_k of .90 or greater for both sides, BLUE would kill all RED fighters, but all BLUE fighters would also be destroyed in the process. If both RED's and BLUE's AAS P_k is less than .87, all BLUE fighters are killed, with some RED fighters surviving. This questions the basis for using any AAS that does not have an appropriate P_k. If we take the known P_k of the AMRAAM in operations, thus far, as .59, then 232 AMRAAM are required to kill 72 opposing fighters, if the overall P_k required is greater than .90. If AAS P_k falls to .10, all BLUE fighter are destroyed, however, 66 RED fighters survive. If BLUE AAS have a P_k of .5, and RED AAS have a P_k of .10, all BLUE fighters are destroyed, while 38 RED fighters survive. Do the odds alter significantly if the size of the Blue force is doubled? In a scenario with 48 BLUE fighters against 72 RED fighters, with the same parameters as previously used, with both RED and BLUE having an AAS P_k of .25, all 48 BLUE fighters would be destroyed, with 43 RED fighters surviving. Even with a P_k of .1 for both, 29 BLUE fighters would be destroyed, leaving 61

[824] *ibid.*, PPF.41.

[825] See generally, Stillion and Perdue, *op. cit.*

RED. BLUE and RED have very few RF BVR AAM remaining, forcing both to enter WVR. BLUE are now outnumber by 2 to 1. The actual number of RED versus BLUE fighters is not unrealistic, when considering the number of tangible fighter assets capable of being deployed, from the total numbers available – for both sides.[826] See Appendix E for a breakdown of AAM exchange rates, with variable kill probabilities.

These examples are designed to illustrate the importance that AAS P_k can have on the outcome of an air-to-air battle, and the significance of mass in numbers. As already highlighted, the importance of AAS P_k and mass needs to be understood.[827] When faced with a peer adversary, the US, or any other state, will need to consider whether it has the necessary weapon systems and balance of forces to gain control of the air.

If modern Western BVR AAS are robust, and stealth is not countered, and secure land- and sea-based operating platforms are available, then current Western air-to-air doctrine is probably adequate, although it would be extremely unwise to rely upon this. There comes a point where quality cannot compensate for sheer force of numbers. History advocates that this limit is a ratio of approximately 3:1.[828] Stillion and Perdue argue that, 'China could enjoy a 3:1 edge in fighters if [the US can fly from Kadena AFB] – [and] about 10:1 if forced to operate from Anderson [AFB]'.[829] Joseph Stalin is reputed to have said, 'Quantity has a quality all of its own'.[830] Perhaps this maxim holds true. The PLAAF training and operational doctrine is not, yet, as sophisticated as the USAF. However, they will not lack numbers when it comes to counter-air assets. In 1992 the PLA had approximately 5000 fighter and ground attack aircraft, with less than 50 considered modern, 4th generation fighters. By 2012, China had reduced its total to 1900 fighter and ground attack aircraft, but with many considered 4th generation, including 268 J-10 and 405 Su-27/30.[831] By comparison the US had more than twice as many such combat aircraft, with 3020 fighter

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[826] Eric Gons explores a similar scenario, detailing the likely assets that would be available to the US, versus the PRC. His conclusions, using analysis of various P_k figures for AAS, are in line with the author's – see Eric Stephen Gons, *Access Challenges and Implications for Air Power in the Western Pacific,* Pardee RAND Graduate School, 2011, pp.98-113.

[827] Wg Cdr Chris Mills, argues that Western air systems and AAM, even with a good P_k, will not necessarily be able to establish air superiority in some scenarios, due to a lack of overall systems effectiveness – see Mills, 'Will the US Air Force Be Annihilated in the Next War?', *op. cit.*

[828] John Mearsheimer argues that the 3:1 rule, which emerged in Europe between the Franco-Prussian War and World War 1, is relevant and has achieved widespread acceptance amongst the modern great powers - see John J. Mearsheimer, 'Assessing the Conventional Balance - the 3:1 Rule and Its Critics', *International Security* Vol 13, no. 4, 1989', pp.56-62.

[829] Stillion and Perdue, *op. cit.,* PPF.31.

[830] There is no reputable source to confirm whether Stalin actually said this, however, it could stand as a truism on its own.

[831] Abdullah, *The Military Balance: 2013*, p.48.

and ground attack aircraft fourth-generation, and 212 fifth-generation.[832] This imbalance will not last. It is projected that the PLA will increase its combat aircraft inventory significantly in the coming decades. Analysis varies; however, by 2020 the PLAAF could be able to field 450+ Flanker type fighters.[833] Air Commodore Ramesh Phadke, a retired Indian Air Force officer, believes that by 2030, '…the PLAAF and PLAN would have 800+ J-10, another 800 Su-30/J-11Bs, and many JF-17… advanced trainers and [a number of] fifth generation stealth fighters'.[834] Although the PLAAF have a way to go in attaining anything like the capabilities of their Western counterparts, significant progress is being made. In testimony presented before the *US-China and Security Review Commission* in 2010, Roger Cliff, an analyst with the RAND Corporation stated:

> ….Many of China's fighters are now capable of carrying BVR missiles, China operates at least a dozen AEW&C aircraft, many strike aircraft are now equipped with precision-guided munitions… and China's EW capabilities have improved substantially too. Many Chinese fighter pilots are now believed to receive roughly the same number of training hours as their U.S. counterparts, and the quality and realism of training has also improved…Finally, China has had an additional ten years to absorb the modern doctrinal guidelines issued in 1999.[835]

Cliff also stated that, 'China's air forces are no longer those of a third-world country. Improvements in China's air force capabilities …mean that prevailing in an air war with China will be increasingly challenging'.[836] The use of large numbers of converted unmanned fighter aircraft, and purpose built UAS, would also add to targeting difficulties – these would still require engagement, attriting own AAM stocks; the problem would be even greater, if these were able to conduct EA and launch their own AAM.[837] What, therefore, is the solution? Quality will not necessarily be the answer to an adversary that has effective counter-air systems, with a numbers advantage. Perhaps it is the utilisation of UCAS, able to operate independently from centralised control, when required. UCAS could operate at great range and for long periods from bases, both land- and sea-centred. These could field current AAM, with an appropriate AAS P_k (calculated, taking into account AAM load-out), in all contested scenarios. The questions are - how much degradation of BVR AAM performance can the Western concept of gaining control of the air accept? If AAM are not the panacea to gaining control of the air, then what is? Other weapon systems would be

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[832] *Ibid*., p.44.

[833] Richard Weitz, 'U.S. Air Superiority Remains Safe', *China US Focus*, 2 September, 2011, http://www.chinausfocus.com/slider/u-s-air-superiority-remains-safe/, (accessed 4 November 2011).

[834] Air Commodore Ramesh Phadke, 'Future of Asian Air Power - 2030', *Indian Defence Review*, 16 February 2011, http://www.indiandefencereview.com/defence%20industry/Future-of-Asian-Air-Power-2030.html, (accessed 15 June 2011).

[835] Roger Cliff, 'The Development of China's Air Force Capabilities', May 2010, http://www.rand.org/content/dam/rand/pubs/testimonies/2010/RAND_CT346.pdf, (accessed 14 May 2011), p.3.

[836] *ibid.,* p.10.

[837] See Singer, *Wired for War,* p.246.

required, such as on-board DEW, aligned with other game-changing technologies which may confuse an adversary's situational awareness enough to gain the advantage - that is, gaining air control of the air for the defined period required.

UCAS Concept of Operations

Already in development, probably becoming operational towards 2020, UCAS capable of ISTAR and SEAD missions will form part of the matrix of future air forces' combat air power. If an air-to-air role is to be developed, an appropriate CONOPS needs to be devised for the operation of these systems. RAND's, *Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century,* offers the view that tactical fighter aircraft may not be the optimum platform for providing counter-air capabilities in locations so far from the nearest viable air base:

> An alternative [to conventional fighters] might be a larger aircraft capable of carrying a large number (e.g., 20 or more) of extremely long-range (e.g., 200 nm) air-to-air missiles. Such an aircraft could engage Chinese fighters while still beyond the range of their missiles and then withdraw before it could be engaged by any of the survivors...[838]

Conceptually, this at least has some merit, and UCAS may be able to fulfil this task. A doctrine of swarming airborne assets may also be an option, certainly for UCAS tasked with conducting TST ISTAR and SEAD missions.[839] A swarming concept for UCAS would consist of a group of UCAS operating in support of both manned and unmanned units. Swarm technology would allow the mission commander to use NEC to monitor UCAS, both individually and as a group. NEC would connect UCAS to each UCAV and the swarm mission commander. The UCAV within the swarm would fly automatically to an operating area. It is intended that these UCAS would conduct area searches, as directed within pre-programmed systems, automatically processing imagery and detecting threats and targets, through the use of AI and NEC, fusing sensor information and image processing. The *Modus Operandi* of swarming allows UCAS networks to de-conflict and assign the best UCAS to each task.[840] Before this could happen, however, control of the air is required. This same swarming technology could be used to conduct counter-air missions.[841]

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[838] Cliff and others, *Shaking the Heavens and Splitting the Earth,* p.240.

[839] For an example of the research ongoing into this type of capability, see Cevik and others, *op. cit.,* pp.595-608.

[840] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047,* p.34.

[841] Banks, Vincent, and Phalp, *op. cit.,* pp.9-29.

Autonomy will be incorporated where it increases overall effectiveness of UCAS. Currently, automation is implemented in UAS to decrease operator workload and increase efficiency. This can include both auto take-off and landing, and transit operations. The terms autonomy and automation have been discussed previously. Autonomy can be viewed as more dynamic than simple pre-programmed flight in that the aircraft will manoeuvre automatically, based on sensors inputs from internal and external sources that include manoeuvring to avoid threats, such as IADS. The US concept certainly envisages that some autonomy will also apply to ground operations, maintenance and repair. Aircraft will integrate with other vehicles and personnel on the ground during launch and recovery, including auto-taxi.[842] If it is deemed necessary to have a HITL at all times, UCAV could operate as part of a COMAO package, acting as wingman to a manned fighter, or even a C2 asset, such as AWACS. This concept differs from swarming in that UCAV will accompany and work with a manned aircraft in the battlespace, acting as ISTAR assets, also capable of delivering kinetic effective, greatly increasing the situational awareness and airborne weapons available. Wingman UCAV could also act as a refuelling asset.[843]

Two of the main strengths of UCAS, range and endurance, would mitigate the requirement for a large number of AAR assets. UCAV with capabilities of remaining airborne for 30+ hours (refuelled), with time on task periods of 5-10 hours, would allow for fewer air vehicles, and consequently less AAR assets. Although still necessary, these AAR assets would not be required to operate at distances close to adversary counter-air assets rendering them inherently vulnerable. A report from the US Center for Strategy and Budgetary Assessment, *The Unmanned Combat Air System Carrier Demonstration Program*, believes UCAS design features may give a potential endurance of up to 100 hours. The report gives examples of the number of UCAS required, versus manned fighters/bombers, operating at ranges from 1500 to 3000 nm from land bases or carriers: '…UCAS would be two to six [times] as effective as manned alternatives in generating persistent "Combat CAPs"'.[844] Although the report is thorough and meticulous in examining the advantages that UCAS would bring, it only mentions air and cruise missile defence once.[845] It would seem that the report believes that control of the air is assumed to be achievable by UCAS, although it does not detail any specific requirements regarding weapon systems. Manned ISTAR

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[842] *United States Air Force: Unmanned Aircraft Systems Flight Plan 2009 - 2047,* p.33.

[843] *ibid*., p.34.

[844] Work and Ehrhard, *op. cit.*, pp.32-33. Among others technological challenges, advances in engine capabilities would be required. AFRL are working on a new combat-aircraft engine, that may improve fuel efficiency by 25%, while increasing supersonic-cruise radius by 50% - see Graham Warwick, 'AFRL Backs New Type of Combat-Aircraft Engine', 24 September 2012, http://www.aviationweek.com/Article.aspx?id=/article-xml/AW_09_24_2012_p31-497914.xml, (accessed 4 October 2012).

[845] Work and Ehrhard, *op. cit.*, p.48.

facilitating nodes, such as AWACS and ELINT aircraft may still be required; it is envisaged though, that the 'systems' available, as part of the 'system of systems' utilised by UCAS, would enable these very HVAA to remain outside of adversary threat systems. The aerodynamic characteristics of UCAV would depend on the robustness of NEC and the types of weapons employed.

The effectiveness of current counter-air AAS has been examined. Unless dramatically improved, the AAM part of the AAS will need to be replaced with other means of defeating an adversary's counter-air aircraft. Assuming that NEC continues to feature as a critical node in warfare, and that whatever weapons are used are integrated into an overarching 'system of systems', a counter-air UCAS would require the capability to achieve altitudes of 50,000 ft.+, and a supersonic dash speed of at least Mach 2, that is at least as capable as Su-35, J-20 or PAF-FA fighters. This speed and height capability allows a greater ability to avoid threats, and to use energy advantage when employing AAM. The UCAV would need the ability to manoeuvre aggressively for defensive purposes, but not to achieve a position in order to employ weapons, as HOBS systems would be used. The UCAV would need to be of such a size that it could contain enough fuel to achieve an operating radius of 1500 nm, the probable range of China's ASBM while maintaining on station for at least 1 hour, with 30 minutes of combat fuel, unrefuelled.[846] This should enable a safe separation to be established between highly capable A2/AD weapon systems and operating platforms. Some effectiveness will be lost if denial systems are developed that have greater range. If this occurs, the basis on which such UCAS were developed would still have efficacy, although, greater emphasis would be required on AAR assets. Current UCAS programmes, such as the X-47B, propose a UCAV that will not be capable of supersonic speed or a high altitude capability, even with up-rated engines, or high 'G' manoeuvrability.[847] The question is, could this system survive against the air-to-air component of a highly sophisticated IADS, unless supported by appropriate counter-air systems?

Concentration of force is a fundamental principle of war that is well suited to air power. As previously described, when this is used, particularly with combat air power, experience has shown that air power concentrated in both time and space is more

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[846] These figures are based on current conventional counter-air aircraft capabilities, operating from relatively close land bases. For examples of combat aircraft range and radius of operation capabilities, see Federation of American Scientists, 'Combat Aircraft Specifications', http://www.fas.org/spp/aircraft/table_ag.htm, (accessed 9 September 2010). See also, China's A2/AD capabilities in Chapter 6.

[847] Northrop Grumman, 'X-47B UCAS-D: Unmanned Combat Air System Demonstration', 2010, http://www.as.northropgrumman.com/products/nucasx47b/assets/UCAS-D_DataSheet_final.pdf, (accessed 23 October 2010). See also, Work and Ehrhard, *op. cit*., Part III, p.39.

effective in achieving an objective than if it were dispersed over a wider area and longer time. Moreover, a concentrated force will use support forces more efficiently, increasing overall capability and survivability. The COMAO concept involves packaging a large number of aircraft, with a variety of roles, complementing each other, in order to achieve a task. A COMAO formation normally consists of counter-air, strike, AAR, ISTAR and other supporting assets. As with manned aircraft, it will be vital that UCAS operating deep within adversary territory, if denied reach-back because NEC is compromised or inadequate, are able to continue to conduct the tasked mission. If unable to continue the mission, autonomously if necessary, UCAS, or any other platform for that matter, would be valueless. In this instance, 'autonomous' means operating independently of C2, as would manned systems. One of the benefits of operating in large formations, includes minimising attrition by optimising mutual support and saturating adversary IADS. Fundamental to the future employment of UCAS, must be their ability to operate within a COMAO package. The following is an example of a COMAO formation flown during the 1991 Gulf War by US forces, against Baghdad C2 facilities:

Target: Baghdad C2 Facilities:[848]
Over the Target Time: 1200 – 1220Z
Assets and Mission:
24 x F-16 – destroy specified targets (ATTACK)
08 x F-15 – offensive counterair (ESCORT)
04 x F-4G – suppression of enemy air defenses (SEAD)
04 x F-16 – suppression of enemy air defenses (SEAD)
02 x EF-111 – close-in-jamming (CIJ)
02 x EF-11 – stand-off-jamming (SOJ)
01 x EC-130 – communications jamming
04 x RF-4C – tactical reconnaissance
08 x KC-135 – air-to-air refuelling (AAR)
01 x E-3A – airborne warning and control system (AWACS)
04 x F-15 – defensive counterair (DCA)

Note the DCA/OCA assets required for this mission. Future military actions, and specifically air power, should still be based on the same principles that apply today, that is, DCA, OCA, attack and ISTAR capabilities. Although the emphasis of air power may change, its characteristics of reach, speed and flexibility are likely to remain relevant. With the advent of improved IADS, stealth technology may become less effective, with persistence, EA capability, payload, discrimination and counter-measures, being the vital components of an air battle. Weapon and detection systems that are able to stand-off,

[848] Major J. Scott Norwood, USAF, *Thunderbolts and Eggshells: Composite Air Operations During Desert Storm and Implications for USAF Doctrine and Force Structure',* School of Advanced Airpower Studies, Maxwell Air Force Base, AL: 1994, http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA285156, (accessed 24 December 2009), p.12.

outside of threats, may offer an alternative form of counter-air and counter-IADS capability. UCAS could offer this option. The US is at the forefront of developing CONOPS for UCAS.[849] For now, let us assume that UCAS will be utilised. With this in mind, a comprehensive doctrine on UCAS employment can be developed. If it is accepted that control of the air is vital in any campaign against a capable adversary, and that UCAS could undertake this task, how would UCAS be employed? Current counter-air Tactics, Techniques and Procedures (TTP) have aircraft such as the F-22 Raptor, F-15C Eagle and Typhoon conducting operations in accordance and within a defined CONOPS, developed over many decades of experience - as described in Chapter 4. While a CONOPS is required for a UCAS, regardless of whether aircraft are manned or not, the doctrine with which air, sea and land forces are employed will likely remain constant. It is proposed that UCAS would use the same TTP.

It may be possible for a large COMAO formation of combat and support aircraft, combining manned aircraft and UCAS, or made up entirely of UCAS, to operate together or autonomously. This autonomy may permit a quicker and more accurate response, with UCAS utilising automated flight and mission management systems, such as the Dynamic Airborne Mission Management system already mentioned, which could also be used by manned aircraft.[850] If these management systems reach a level of capability allowing them to be trusted to an acceptable level, then HITL would not be required, for other than legal considerations. Using the author's autonomy levels, Level 4 would be the normal envisaged operating mode, with a HOTL only intervening if required. Level 5, giving full autonomy, would be implemented if communications links were lost, and the importance of the mission was deemed crucial enough to warrant the potential risks that this may involve.

[849] For example, see Alkire and others, *op. cit.,* pp.33-54.

[850] Bonner, Taylor and Fletcher, *op. cit.,* pp.157-158.

Chapter 6: International Relations and Future Threats

Introduction

The issues that form military doctrine and political policies towards international relations are complex.[851] The types of military systems required to enforce these doctrines and policies are predicated on the likely scenarios that states may encounter. It is important, therefore, to have an understanding of where future threats are likely to emerge. Only then, can coherent strategic doctrine be formulated, and the correct military equipment procurement and training policies implemented. No country or region should be viewed in isolation, but rather how they relate to each other. This is a fundamental premise of international relations. Whether there will be major state-on-state conflicts in the coming epochs is debateable. Rupert Smith, in *The Utility of Force,* argues that major state-on-state wars, involving the whole population and industrial complex are highly unlikely, and that our armed forces need to be reorganised to fight different types of conflicts. Smith believes there is a, '…new paradigm of war amongst the people [which] is based on a continuous criss-crossing between confrontation and conflict…Rather than war and peace, there is no predefined sequence, nor is peace necessarily either the starting or the end point…'.[852] Smith considers there are six major trends for what he terms as 'war amongst the people', with the primary being - 'The ends for which we are fighting are changing from the hard absolute objectives of interstate war to more malleable objectives to do with the individual and societies that are not states…'.[853] The remaining are: 'We fight amongst the people…Our conflicts tend to be timeless…We fight so as not to lose the force…On each occasion new uses are found for old weapons…[and]…The sides are mostly non-state…'.[854] While Smith's views are worth considering, there are other opinions.

Colin Gray believes that although future wars between states cannot be predicted, they are likely to occur; he states: 'We can predict with confidence that the future will register war of

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[851] For an overview of the considerations for the planning and implementation of military and non-military strategy, and the nature and evolution of strategy and the changing role of military force, see generally, John Bayliss and others, *Contemporary Strategy II*, 2nd Edition, New York: Holmes & Meier Publishers, Inc., 1987, See also, Bradley S. Klein, *Strategic Studies and World Order*, Cambridge: Cambridge University Press, 1994, pp.13-31.

[852] See Rupert Smith, *op. cit.,* pp.16-17. For a view on the role of people and states in future wars, which offers a different perspective to Smith's, see Pascal Vennesson*, 'War without the People', in The Changing Character of War*, Hew Strachan and Sibylle Scheipers (eds), Oxford: Oxford University Press, 2011, pp.241-251.

[853] Rupert Smith, *op. cit.,* p.17.

[854] *ibid.,* p.17.

many kinds between states'.[855] Amongst other possible conflicts, Gray hypothesises that a China versus the US clash, either over Taiwan, or hegemony in East Asia, is possible, with both countries arguing each is the defining threat for national security.[856] Gray does not wish to give the view that this type of conflict is a certainty, but he emphasises that it would be prudent to be prepared for 'strategic surprises'. Perhaps Gray's most important observation, is his belief that, '….the future of warfare will contain interstate conflicts that no one today who carries weight as a supposed expert on the future is imaging'.[857]

Michael Howard, in *The Invention of Peace & the Reinvention of War,* discusses the probability of major state-on-states wars, and while opining that these are becoming less likely, believes nations such as China, Russia and the US, will offer the potential for confrontation.[858] The historian Hew Strachan suggests that a lack of understanding of the true nature of war has led to a failure to understand its 'changing characteristics'.[859] Strachan believes that: 'Wars have become fuzzy at the edges: they have no clear end and army forces increasingly have to reject the appropriateness of classical definitions of military victory'.[860] Strachan is of the view that while these issues, '…deserve coordinated action…[they]…are not wars, and so many so-called security issues are being resolved without a military dimension'.[861] Another view comes from Azar Gant from Tel Aviv University, who believes that, although the probability of major wars remains low, does wonder if the '…near disappearance of armed conflict within the developed world is likely to remain as stark as it has been since the collapse of communism'.[862] Gant views that the re-emergence of capitalist non-democratic states, such as China and Russia, is a paradigm shift in international relations.[863] Strachan further argues that we are likely to see a change back to the ideas of deterrence and limited war.[864] Strachan believes: 'The wars of the

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[855] Colin Gray, *Another Bloody Century*, p.177.

[856] *ibid.,* p.199.

[857] *ibid.,* pp.183-184.

[858] See Michael Howard, *The Invention of Peace & the Reinvention of War*, London: Profile Books, 2001, pp.99 and 101-102.

[859] Hew Strachan, *The Changing Character of War (Europaeum Lecture)*, Oxford: The Europaeum, 2007, p.31.

[860] *ibid.,* p.3.

[861] *ibid.,* p.27.

[862] Azar Gat, 'The Changing Character of War', in *The Changing Character of War*, Hew Strachan and Sibylle Scheipers (eds), Oxford: Oxford University Press, 2011, p.30.

[863] *ibid.*

[864] Hew Strachen, 'Strategy', in *The Future Character of Conflict,* Hew Strachan and Sibylle Scheipers (eds), Oxford: Oxford University Press, 2011, pp.514-520.

later twenty-first century may well be waged for assets, to which we feel in theory all humanity should have equal access but for which in practice we compete'.[865]

Following World War II, and the devastating attacks on Nagasaki and Hiroshima, Bernard Brodie, one of the most imminent theorists of strategic deterrence, wrote: '….Thus far the chief purpose of our military establishment has been to win wars. From now on its chief purpose must be to avert them. It can have almost no other purpose'.[866] Brodie's remarks capture the essential reason for a nation possessing armed forces. He succinctly stated: 'The threat of war, open or implied, has always been an instrument of diplomacy by which one state deterred another from doing something of a military or political nature which the former did not wish the later to do'.[867] Perhaps Brodie's most prescient observation was the likelihood that one's own behaviour in extremis is unpredictable, let alone that of an adversary's: 'The wrong kind of prediction in the future could precip[it]ate the total war which too many persons have lightly concluded is now impossible'.[868]

It is not possible to predict future events; it is, however, possible to learn from previous events, and to apply sound analytical judgement to the state of current international affairs, enabling the formulation of coherent policies. Most major nations utilise think tanks and other institutions to help devise strategic policy.[869] For example, the UK's MOD's DCDC is the UK Defence institution for doctrinal, conceptual and future scenario development. DCDC produces concepts and doctrine - underpinned by research and experimentation, with the aim to help inform decisions in UK defence strategy and capability development.[870] What makes a state a super power? Analysis from DCDC defines power status as: '…the amalgam of military strength, access to resources, size of economies, educational opportunity, demographics, geo-political position and political stability amongst others'.[871] China uses its own method of calculating a nation's power – Comprehensive National Power (CNP). While there is no unified definition or method of calculation with regard to

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865 *ibid.,* p.520.

866 Bernard Brodie (ed), *The Absolute Weapon: Atomic Power and World Order*, New York: Harcourt and Brace, 1946, p.76. Brodie was writing with reference to a nuclear deterrence and expanded on his thoughts in, Bernard Brodie, 'The Development of Nuclear Strategy', *International Security* 2, no. 2, 1978, pp.65-83.

867 Bernard Brodie, *The Anatomy of Deterrence*, Santa Monica, CA: RAND Corporation, 1958, p.3.

868 *ibid.* pp.6-7.

869 The RAND Corporation, RUSI, IISS, Chatham House, Brookings Institution, and the Council of Foreign Relations, are all examples.

870 Development, Concept and Doctrine Centre, 'What We Do', 2011, http://www.mod.uk/DefenceInternet/MicroSite/DCDC/WhatWeDo, (accessed 24 February 2011). DCDC's analyses are but one source of views. Their views do not need to be endorsed, but they do offer peer reviewed analysis.

871 Development, Concept and Doctrine Centre, *Strategic Trends Programme: Global Strategic Trends - out to 2040*, Fourth Edition, Shrivenham: UK Ministry of Defence, 2010, p.38.

CNP, it is generally defined as '…the comprehensive capabilities of a country to pursue its strategic objectives by taking actions internationally and the core factors to the concept are strategic resources, strategic capabilities and strategic outcomes, with the strategic resources as the material base'.[872] Since the demise of the Soviet Union, and while the US is the only current true super power, there is a view among economists that China is likely to overtake the US economically, as early as 2020. According to the UK's National Institute of Economic and Social Research (NIESR), China is likely to overtake America as the world's largest economy by 2019, as Western nations struggle to recover from the global banking crisis.[873] Goldman Sachs estimates that the size of the Chinese economy will overtake America's by 2027, and by 2050 will be almost twice as big.[874] These predictions underline the contrasting fortunes of Asia, which is enjoying rampant growth, and the more subdued economies of the West. China's GDP grew by 10.4% in 2010, compared with 3% growth in the US and 1.8% in the Eurozone. NIESR forecasts that Chinese growth will average 8% a year out to 2018, compared to 2.5% in the US.[875]

While the future world view is impossible to predict, DCDC does, however, attempt to give some judgement as to the likely structure of the future international landscape. DCDC believes:

> The era out to 2040 *will* be a time of transition; this is *likely* to be characterised by instability, both in the relations between states, and in the relations between groups within states. During this timeframe the world is *likely* to face the reality of a changing climate, rapid population growth, resource scarcity, resurgence in ideology, and shifts in global power from West to East….The distribution of global power *will* change. Out to 2040, the locus of global power *will* move away from the [US] and Europe towards Asia, as the global system shifts from a uni-polar towards a multi-polar distribution of power. This shift, coupled with the global challenges of climate change, resource scarcity and population growth, is *likely* to result in a period of instability in international relations, accompanied by the *possibility* of intense competition between major powers. The hegemonic dominance of the US *will* fade. She is *likely* to remain the pre-eminent military power, although, in political, economic and military terms, she is *likely* to be increasingly constrained as others grow in influence and confidence…[876]

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[872] Hu Angang and Men Honghua, *The Rising of Modern China: Comprehensive National Power and Grand Strategy',* Center for China Studies at Tsinghua University, 2004, http://www.irchina.org/en/pdf/hag.pdf, (accessed 19 May 2009), p.3.

[873] National Institute of Economic and Social Research, 'At a Glance: The World Economy', *National Institute Economic Review*, no. 211, January 2010, p.F2.

[874] Goldman Sachs Global Economics Paper No:192, 'The Long-Term Outlook for the BRICs and N-11 Post Crisis', New York, NY: Goldman Sachs, 2009, http://www.goldmansachs.com/our-thinking/archive/archive-pdfs/long-term-outlook.pdf, (accessed 3 February 2012), pp.4, and 22.

[875] Dawn Holland and others, 'The World Economy', *National Institute Economic Review*, no. 219, January 2012, p.F10. China's GDP was 9.2% in 2011 – see Abdullah, *The Military Balance: 2013*, Chap 6, p.256.

[876] Development, Concepts and Doctrine Centre, *Strategic Trends Programme: Global Strategic Trends*, p.10.

While DCDC believes the US will still be the pre-eminent military power in 2040, they assess that China *may* reach great power status – ‘The US is currently the only great power; the major powers are China, Russia, France and the United Kingdom. Japan and Germany are major economic powers. Their status is unlikely to change out to 2040...[while] China may reach great power status by 2040’.[877] DCDC’s views do not have to be agreed with, but they do offer a reasonable baseline. The struggle for control over resources and the global commons may indeed increase the incidents of conflict. The Global Commons is described as, ‘The domains of the high seas, international airspace, outer space, and cyber space are interlinked and critical to the prosperity and security of the Alliance nations. Access to these domains is both a military and economic necessity in today’s world’.[878]

While direct conflict between the UK and a major power such as China or Russia is unlikely, wars involving the major powers is a possibility. As part of a coalition, the UK may be required to confront a near-peer, or even a peer adversary. China will be the benchmark by which the US judges its own capability requirements, and perhaps that of its allies.[879] Although major state-on-state war is not predictable, there will remain the necessity for nation-states to maintain military capabilities that deter potential aggression. Are we possibly seeing a transfer of power, from the US to China, similar to that which took place in the early part of the 20th Century, when Great Britain began to cede its prominence to the US?[880] Other states, such as Russia, North Korea, India, Australia, Brazil, Taiwan and Japan will all play a major part in future international relations. Australia and Japan, in particular, are important economic powers in their own right; however, it is in relation to the security of their near-abroad that these two countries will seek to maintain and build alliances, attempting to balance China’s influence. North Korea will likely continue to be a failed and unstable state, generally undermining the stability of that area of the Pacific.[881] Russia, India and Brazil (part of the so called BRICs) are states whose economies are

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[877] *ibid.,* p.38. DCDC has also produced a survey examining South Asia specifically (Pakistan, China, India, Nepal, Bhutan, Bangladesh, Myanmar and the Maldives) – see generally, Development, Concepts and Doctrine Centre, *Strategic Trends Programme: Regional Survey – South Asia out too 2040,* Shrivenham: Ministry of Defence, 2010.

[878] See Major General Mark Barrett and others, 'Assured Access to the Global Commons', Norfolk: North Atlantic Treaty Organisation, 2011, http://www.act.nato.int/globalcommons, (accessed 12 November 2011), p. ix.

[879] Development, Concepts and Doctrine Centre, *Future Character of Conflict*, Shrivenham: Ministry of Defence, 2009, p. 30.

[880] For a view on the rise of the US, see generally, Niall Ferguson, *Colossus: The Rise and Fall of the American Empire*, London: Penguin Books, 2004.

[881] Utlimately, North Korea's 'brittleness', may lead to its collapse, and a reunitfied Korea. This could, in itself, create further instability in the region - see, Development, Concepts and Doctrine Centre, *Strategic Trends Programme: Global Strategic Trends*, p.62.

growing faster than those in the West, and are predicted to continue to do so. DCDC believe that in 2029 the major powers will be the US, China, Russia, UK, France, India, Japan, Iran and possibly Brazil.[882] Another view comes from Joseph Nye, who believes that although the US is likely to remain the most powerful state in the 21st century, it does not mean it will have domination.[883]

Middle Eastern countries such as Iran and Saudi Arabia will likewise have a significant impact on the nature of international affairs. International attention regarding Iran's intent to gain a nuclear weapons capability drives much of the international communities' current efforts to reign in these ambitions. It is probably too late in North Korea's case, but Iranian containment may be possible, but at what cost? What if Iran does gain nuclear weapons? The effect this will have in the Middle East, and further afield, will test international relations and military doctrine. South America is likewise becoming increasingly important economically, with Brazil, in particular, an important exporter of agricultural products and raw materials. It is quite possible that an alliance of South American powers may align to challenge the UK's resolve over the Falkland Islands, creating tensions between the UK and those who have been traditional allies. Argentina certainly shows no sign of giving up its claims to sovereignty to the Falkland Islands.[884]

This thesis makes comment on, but does not attempt to judge, the current trend of some governments to be selective, when it comes to future international relations and military doctrine, which ultimately drives force structures. Most governments base their military policy and procurement decisions on a range of scenarios in which they have deemed the state is likely to become involved in. Those departments of government that are responsible for foreign affairs and military doctrine usually decide upon these scenarios, which are normally set in future epochs, 2015-2020, 2020-2025, and so on. The UK, for example, uses a set of Studies Assumption Group (SAG) scenarios, developed by the Force Development department of DCDC; these are derived from British Defence Doctrine, to represent realistic examples of the types of operations involving UK forces envisaged by UK government policy. These state:

> The purpose of Force Development is to guide the development of military capabilities and force structures in order to deliver UK defence policy. Force Development provides MOD Main

[882] Development, Concepts and Doctrine Centre, *Future Character of Conflict*, p.40.

[883] Joseph Nye, *The Future of Power*, New York: Public Affairs, 2011, p.xvii.

[884] Abdullah, *The Military Balance: 2013*, Chap 8, p.432.

Building with high quality, evidence-based advice to inform the strategic planning process, guiding decisions on defence policy, capability development and operations.[885]

Within this procedure, there is process which turns these scenarios into credible joint campaign plans, from which the force package necessary to execute the plans is estimated. Each is then evolved into a campaign plan, which is the subject of extensive analysis. The output from these results, referred to as Joint Campaign Development Force Estimation, is used to inform the central planning process within the UK MOD.[886] This procedure is a valid tool; however, if the initial assumptions are flawed, then all subsequent findings will be based on unreliable foundations. Other states use similar procedures to calculate their own force requirements, each placing a different emphasis on their own scenarios. This is one of the causes of such a variation in countries' spending on their defence force structures. Rupert Smith stresses the importance of proper analysis, stating: 'It is…possible to see the vital importance of conducting an analysis based upon the desired political outcome, since it will reveal whether military force can and should be used, and if so to what degree and purpose'.[887]

Colonel John Warden suggests that errors of judgement in assessing potential threats are unforgiveable. He advises, 'The first step in assessing an enemy is a very careful review of intelligence information, followed by dispassionate war gaming, followed by more intelligence collection and analysis, followed by more war gaming, until the answer is relatively certain…'.[888] Both Smith and Warden's observations are very pertinent. Ultimately, the desired political outcome is the primary driver for a state's foreign and military policy, or at least it should be.

James Kurth in *The New Maritime Strategy: Confronting Peer Competitors, Rogue States, and Transnational Insurgents*, believes, '…the most obvious counterpart to the old Soviet Union and the only likely near-peer or peer competitor is China.'[889] Most US strategists currently refer to China as a near-peer competitor, however, this is likely to change in the coming decades to a peer adversary. Iran is not currently a near-peer competitor; its asymmetric approach to military doctrine may mitigate this requirement. The

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[885] British Defence Doctrine is linked to a variety of unclassified policy documents such as Defence White Papers and Strategic Defence Reviews, as well as classified Defence Strategic Guidance. See UK Ministry of Defence, *Joint Doctrine Publication 0-01: British Defence Doctrine*, p.v., para 4.

[886] See The National Archives, *About Defence: DCDC - Force Development* 5 February 2005. http://webarchive.nationalarchives.gov.uk/+/http:/www.mod.uk/DefenceInternet/AboutDefence/WhatWeDo/DoctrineOperationsandDiplomacy/DCDC/DcdcForceDevelopment.htm, (accessed 8 October 2010).

[887] Smith, *The Utility of Force: The Art of War in the Modern World*, p.375.

[888] Warden, *op. cit.*, p.30.

[889] James Kurth, 'The New Martime Strategy: Confronting Peer Competitors, Rogue States, and Transnational Insurgents', *Orbis,* http://www.fpri.org/orbis/5104/kurth.newmaritimestrategy.pdf, (accessed 2 March 2009), p.589.

consequences of the future political and military policies of both China and Iran will have an effect globally, altering strategic, political, and military relationships.

A major realignment in US strategic military thinking is taking place, which is currently budgeted on the capability to fight two major wars simultaneously. Commitment to wars on two fronts, in Iraq and Afghanistan over the last ten years, has coincided with a global economic downturn, which has seriously tested the US economy. Large cuts in the Pentagon's budget were announced in January 2012. As an interim measure, there will be cuts of $260 billion out to 2017. Congressional budget agreements contain a sequestration requirement for $1 trillion, with half coming from the military.[890] This means that if the Pentagon cannot agree on extra cuts, the US Congress will automatically instigate them. Leon Panetta, the US Secretary of Defence in 2012, warned that such large cuts to the military will be disastrous for US national security. Although his pessimism is accepted as a challenge, there are others within the US that do not agree. Professor Gordon Adams, a Fellow at the Stimson Centre, a Washington think tank, points out that even if $1 trillion is cut, this is still only 17% less than currently spent, compared with the cuts to the defence budget after the Korean, Vietnam and Cold Wars, which totalled 30%.[891] The US military chiefs are similarly concerned, however. In a brief to the US House Armed Services Committee in 2011, the four chiefs of the US Army, Air Force, Navy and Marines cautioned that planned budget cuts, and possible sequestration would lead to, '…[a] hollow force unable to provide a proper national defense…[and] of the increasing power of China…'.[892] After delays by President Obama, the US Congress enacted sequestration, and cuts were enacted in March 2013, amounting to $46 billion for 2013/14, to begin with.[893] The challenges faced by the US and others are no less fundamental, simply because the Cold War is long over. Indeed, it is not a straightforward comparison to say that the proposed military budget cuts are far less than previously experienced. The US relationship with Europe, in particular, is likely to be tested.

US focus is shifting towards the Western Pacific, while still seeking to maintain influence in the Middle East. In its new strategic guidance, *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*, it is stated that, 'U.S. policy will emphasize Gulf

[890] Alexandra Frean, 'Cuts Limit US to One War at a Time', *The Times,* 4 January 2012, p.25.

[891] *ibid.*

[892] Christopher P. Cavas, 'Budget Cuts Drive U.S. Hearings', *DefenseNews*, 7 November 2011.

[893] Chuck Hagel US Secretary of Defense, 'DoD Press Briefng on Sequestration from the Pentagon', *U.S. Department of Defense News Transcript*, 1 March 2013, http://www.defense.gov/transcripts/transcript.aspx?transcriptid=5196, (accessed 12 March 2013).

security…to prevent Iran's development of a nuclear weapon capability and counter its destabilizing policies'.[894] It also states that:

> …while the U.S. military will continue to contribute to security globally, *we will of necessity rebalance toward the Asia-Pacific region*. Our relationships with Asian allies and key partners are critical to the future stability and growth of the region. We will emphasize our existing alliances, which provide a vital foundation for Asia-Pacific security.[895]

Aaron Friedberg, a professor at Princeton University, believes that by 2030, the US will probably have withdrawn most of its forces from Europe, the Middle East and Southwest Asia, while, '[A] far greater fraction of the total American military and intelligence effort will be devoted to the Western Pacific, and to the area that extends from the Strait of Hormuz, in the Persian Gulf, through the Indian Ocean to the Strait of Malacca'.[896]

The challenges that an aggressive China will bring to stability, not only in that region, but globally, will test alliances and military doctrine. An editorial, in *The Daily Telegraph,* emphasised the significance of the cuts: 'For decades, the US has underwritten the security of the Atlantic as well as the Pacific, effectively allowing Europe a free ride and permitting a string of [NATO] members the luxury of running down their defence budgets. This era is rapidly coming to a close.'[897] The editorial highlighted the fact that the US was most definitely moving to a more Asia-centric foreign policy, increasing its presence in Australia for example. It also reiterated that China is unlikely to acquiesce to US hegemony in the region:

> Faced with the net of containment that America is quietly laying across the Pacific, China will search for the Achilles' heel of the US Navy, perfecting a new generation of missiles capable of destroying aircraft carriers from hundreds of miles away, working out how to cripple the internet, and how to blind the US satellite network, on which all its military assets now depend.[898]

Friedberg argues that because of their vulnerability to China's emerging A2/AD doctrine, the US will need to reconsider its use of aircraft carriers; also, as China's counter-air capabilities improve, and its land bases become more vulnerable to attack, '…the air force may find itself pressed to spend less on relatively short-range air superiority fighters…and

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[894] US Department of Defense, 'Sustaining U.S. Global Leadership: Priorities for 21st Century Defense', Washington, DC: US Department of Defense, 2012, http://www.defense.gov/news/Defense_Strategic_Guidance.pdf, (accessed 9 September 2012), p.2.

[895] *ibid.*

[896] Friedberg, *op. cit.,* p.241.

[897] Telegraph View, 'The Battle for the Pacific Will Reshape the World', *The Daily Telegraph*, 6 January 2012, http://www.telegraph.co.uk/comment/telegraph-view/8998411/The-battle-for-the-Pacific-will-reshape-the-world.html, (accessed 6 January 2012).

[898] *ibid.*

more on stealthy long-range bombers and unmanned aerial vehicles'.[899] This view, which the author agrees with, is at the centre of the UCAS counter-air discussion.

Whether the EU as a collective, or European countries as individual states, have the ability, or indeed intent, to become embroiled in a Pacific/Asia-centric strategic scene in the coming decades, cannot be evaluated with any confidence. However, inadequate analysis may lead to a situation where the lack of willingness to become involved in any stabilising or deterrent measures could lead to the wrong interpretation by belligerent states. Economic constraints necessarily drive a country's foreign policy and military aspirations. These same constraints may well mean a compulsory contribution is required, if domestic stability and reliable trade mechanisms are to remain the primary objective of the state.

The author seeks to establish the most likely scenario in which a major state-on-state conflict will occur in the 2030-2040 period. This does not mean that a future conflict can be predicted with any accuracy. It is axiomatic, however, that recent conflicts such as Bosnia, Kosovo, the 1991 Gulf War, Afghanistan, and the 2011 Libyan uprising, were not factored into any defence planning assumptions by the US or UK, to any great extent.[900] In order to enable the correct policy decisions to be formed, it is essential to consider all viable scenarios, which can only be relevant if a thorough understanding of the intent of potential adversaries is gleaned. This thesis concentrates analysis on China and Iran, with regard to the effect these states' international policies will have on the US and its allies' relationships with them. Countries' foreign policies, such as those of US, Taiwan, Japan, Russia and India, will have a significant effect on China's foreign and military doctrine, thus affecting the future security of the Western Pacific, and further afield. Iran's position in the Middle East also poses a significant conundrum for international politics; both of these areas will be the likely centres of gravity over the coming decades, at least for the US and its allies. China and Iran pose similar problems, with the likelihood that both will use A2/AD doctrine, forcing adversaries to operate outside their current optimum basing constraints.[901]

China

To fully understand the rise of China, from a Dynastic power, to the communist system it is today, would be a PhD thesis in itself. This thesis does not venture down that road. An appreciation of China's path, is, nonetheless, fundamental. There are a number of

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[899] Friedberg, *op. cit.,* p.117.

[900] Charles Kupchan and Whitney Shepardson, 'A Still-Strong Alliance', *Council on Foreign Relations*, April/May 2012, http://www.cfr.org/europerussia/still-strong-alliance/p27818, (accessed 7 August 2012).

[901] US Department of Defense. 'Sustaining U.S. Global Leadership: Priorities for 21st Century Defense', pp.4-5.

excellent works of reference that detail China's progress; these have helped the author to understand some of the reasons behind China's internal and foreign policies.[902]

China is dominating current international affairs, not only in regard to its position in the world economy, but also in relation to its military build-up and intent. China is no longer the insular state it once was; over the past 30 years, great progress has been made in its pursuit of economic growth and development, enabling higher living standards for its people and increasing its international profile.[903] These economic achievements, combined with progress in science and technology, have also enabled China to embark on a comprehensive transformation of its military. With this economic success has come a revival of the view within China that it should be appreciated for what it is - a great power, and the pre-eminent one in Asia.[904] Martin Jacques, in *When China Rules the World,* believes: 'We are now witnessing an historic change which, though still in its relative infancy, is destined to transform the world'.[905] China, as a civilisation, has existed for longer than any other comparable society. Henry Kissinger in, *On China,* believes that the history of China as a civilisation seems to have no beginning, 'It appears in history less as a conventional nation-state than a permanent natural phenomenon'.[906] Jacques also believes that China should not be seen primarily as a nation-state, but be viewed as a civilisation.[907] Jacques states, 'China has existed within roughly its present borders for two thousand years and only over the last century has it come to regard itself as a nation-state'.[908] Since its unification in 221 B.C., until the early 19th Century, China's rulers, through all its dynasties, took the view that China was the most important civilisation, by

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[902] Although not an exhaustive list, among the best works are: Jonathan Fenby, *The Penguin History of Modern China: The Fall and Rise of a Geat Power 1850 - 2008*, London: The Penguin Group, 2008; Odd Arne Westad, *Restless Empire: China and the World since 1750*, London: Random House, 2012; John Keay, *China: A History*, London: Harper Press, 2009; Henry Kissinger, *On China*, London: Penguin Books, 2011; Thomas J. Christensen, *Useful Adversaries: Grand Strategy, Domestic Mobilization, and Sino-American Conflict, 1947-1958*, Princeton, NJ: Princeton University Press, 1996; Jung Chang and Jon Halliday, *Mao: The Unknown Story*, London: Vintage, 2007.

[903] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, Washington, DC: 2010, http://www.defense.gov/pubs/pdfs/2010_CMPR_Final.pdf, (accessed 19 May 2010), p.I. For a view on how important the rise of China is in international relations, see generally, George Walden, *China: A Wolf in the World*, London: Gibson Square, 2008.

[904] From the Han Dynasty in 202 BC, to the Qing Dynasty in 1912 (the last), China has, for most of these periods, seen itself has the 'centre' of the world. For a short synopsis of China's path from a Dynastic state, to the formation of Mao's People's Republic of China, and Chiang Kai-shek's Nationalist China (Taiwan), see - Keay, *op. cit*., pp.480-535.

[905] Martin Jacques, *When China Rules the World*, London: Penguin Books, 2012, p.2.

[906] Kissinger, *op. cit.*, p.5.

[907] Jacques, *op. cit.,* p.18.

[908] *ibid.* p.17.

far.[909] Indeed, until the late 19th Century, China produced a greater share of the world's GDP than any other society.[910]

The fundamental social change China has undergone since the 1970s has shifted its aspirations and changed its worldview. It is an economic dynamo, and as previously highlighted, is likely to usurp the US as the world's No 1 economy in the coming decades.[911] Its armed forces remain the world's largest and are being reorganised and re-equipped to enable them to meet any perceived threat. The historian, Niall Ferguson, believes that Western dominance in the World order is rapidly coming to an end; he cites the fact that in 1970, China was 1/70th as rich as the US, while in 2010, it was 1/5th as rich.[912] Ferguson believes that China and the US do not have a symbiotic relationship, and that any relationships built up thus far, are likely to decline, hastened by the change of Chinese leadership in 2012. Perhaps Ferguson's most important observation is that Chinese policies are non-linear, with a very high-level of unpredictability.[913]

According to the *Annual Report to Congress: Military and Security Developments Involving the Peoples' Republic of China 2010*, the overriding drivers for China are, currently: '…ensuring internal stability; reunification of Taiwan; gaining respect for its perceived global position; a balanced continuation of its economic development; and the securing of its energy supplies, including the routes through which they pass'.[914] Aaron Friedberg sees China's view of the future as, '…the strategic situation is characterized by tenuous near-term stability, serious medium-term dangers, and expansive long-term possibilities'.[915] China may historically have no inclination to control its neighbours' territory; however, it will likely reinforce its vision that it is the key regional power, which will defend itself, will not be threatened, and will protect what it identifies as its legitimate interests. Although China's

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[909] Kissinger, *op. cit*., pp.7-12.

[910] In 1870, China's GDP was $189,740 million, while the US's was $98,374 million. In 1913, the US GDP was $517,383 million, while China's was $241,344 million – see Angus Maddison, *The World Economy: A Millennial Perspective*, Paris: OECD, 2001, Table B-18, p.261.

[911] Although difficult to pinpoint, China's economic rise essentially began in 1971, when the US dropped its economic embargo, and China took Taiwan's place as a permanent member of the UN Security Council – see Jonathan Fenby, *Tiger Head, Snake Tails: China Today, How It Got There and Where It Is Heading*, London: Simon & Schuster, 2012, pp.164-194.

[912] Professor Niall Ferguson, 'Transcript: The West and the Rest: The Changing Global Balance of Power in Historical Perspective', London: Chatham House, 9 May 2011, http://www.chathamhouse.org/sites/default/files/19251_090511ferguson.pdf (accessed 19 August 2012), p.3.

[913] *ibid.,* p.19.

[914] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010*, pp.15-17. These 'Annual Reports' offer an insight into the US thinking on China's military development. Reports from 2010 to 2013 are used in this thesis.

[915] Friedberg, *op. cit.,* p.142.

leadership emphasises its peaceful intentions, some international relations theorists believe that this is not the case, with the use of 'soft power' and 'string of pearls' strategies to mislead the international community.[916] Professor Joseph Nye developed the concept of soft power in 1990, which he describes as, '…getting others to want the outcome you want – co-opts people rather than coerces them'.[917] China is not the only major state to use 'soft power – the US has been a proponent for decades, not least, following World War II, with the introduction of the Marshall Plan.[918] Others, such as Avery Goldstein, do not consider this China's intent. Goldstein states in *Rising to the Challenge: China's Grand Strategy and International Security*:

> There is…scant evidence at present on which to base predictions that China is likely to abandon its current, relatively conservative approach and instead adopt a grand strategy that would seek to overturn, rather than adjust to or reform, the international order it faces.[919]

Whichever views are correct, China's growing economic stature helps its drive for a more active external posture in which it is prepared to demonstrate a willingness to assert its interests. In a significant move from its normal rhetoric, China's 2008 Defence White Paper states that:

> China has become an important member of the international system and the future and destiny of China have been increasingly closely connected with the international community. China cannot develop in isolation from the rest of the world, nor can the world enjoy prosperity and stability without China.[920]

Mitsuru Kitano, a Japanese diplomat, believes China is tending towards a China-centric order, as opposed to a responsible Great Power path.[921] Kitano argues that: 'To judge from the dynamics of China's international relations at the present time, it seems that the China-centric order course will become more dominant as China's national strength

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[916] The phrase 'String of Pearls' was first used to describe China's emerging maritime strategy in a report titled "Energy Futures in Asia" by defence contractor, Booz-Allen-Hamilton - see Chistina Lin, *The New Silk Road: China's Energy Strategy in the Greater Middle East*, Washington, DC: The Washington Institute for Near East Policy, 2011, pp.10-12

[917] For the definitive explanation of what soft power is, including its limitations, see Joseph Nye, *Soft Power: The Means to Success in World Politics*, New York: Public Affairs, 2004, pp.5-17. For Nye's description of his term 'Smart Power', which is a combination of 'Soft Power' and 'Hard Power', that is military power, see Nye, *The Future of Power*, pp.22-24.,

[918] For a view on China's doctrine of regional 'soft power', and its relationship with the US, see Shaun Breslin, 'Understanding China's Regional Rise', *International Affairs* 85, no. 4, 2009, pp.827-834.

[919] Avery Goldstein, *Rising to the Challenge: China's Grand Startegy and International Security*, Studies in Asian Security, Stanford, California: Stanford University Press, 2005, p.211.

[920] Information Office of the State Council of the People's Republic of China, 'China's National Defense in 2008', Washington: Federation of American Scientists, January 2009, http://www.fas.org/programs/ssp/nukes/2008DefenseWhitePaper_Jan2009.pdf, (accessed 10 March 2010), p.1.

[921] Mitsuru Kitano, 'China's Foreign Strategy', *Asia-Pacific Review* 18, no. 2, 2011, pp.37-59.

increases and its relative importance in the international community grows'.[922] Martin Jacques, writing in *The Times,* views China's rise from an historical perspective, believing that, '…the Chinese do not think of themselves in terms of nation but civilization; it is the latter that gives them their sense of identity'.[923] He firmly believes that China's rapid growth will lead to a reconfiguration of the region: '….It is entirely plausible that we might once again see the return…of some elements of the tributary state system,… challenging the global dominance of [the] European [the Westphalian system] of sovereign independent nation states...'.[924] He goes further, stating: 'The rise of China signals the slow dawning of a very different era in which Chinese influence will become profound…'.[925]

PLA military strategists perceive the US as posing both an immediate and long-term challenge to Chinese national security interests. This perception is based on a set of concerns about US policies on Taiwan, US alliance relationships and defence ties in Asia, and overall US national security strategy.[926] Japan's re-emergence as a regional military power, India's growing military power and regional influence, its own border and coastal defence, and defending its territorial waters and airspace, are also viewed as critical areas.[927] The writings of Chinese military officers, and official government assessments, suggest a range of specific threats and potential challenges to Chinese security. These perceptions drive current and future directions in doctrine and force structure planning. While most Chinese commentators do not see a rapid decline in the US's comprehensive power, they do believe Iraq and Afghanistan have weakened its position in the world, and it is inevitable that the US's hegemony in Asia will erode.[928] Niall Ferguson certainly believes that the 'West' is in steady decline, while the 'East', in particular China, is on the ascendency.[929] This decline may happen more quickly than anticipated; Ferguson gives examples of 'Empires' that have had relatively quick declines: The Soviet Union in 1991, The British Empire after 1945, Japan after 1942, and the Ottoman Empire in 1921, for example.[930]

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[922] *Ibid.*, p.52.

[923] Martin Jacques, 'Currency, Culture, Confuscius: China's Writ Run across the World', *The Times*, 24 June 2009, p.28.

[924] *ibid.*

[925] *ibid.*

[926] Keith Crane and others, *Modernizing China's Military: Opportunities and Constraints*, Santa Monica, CA: RAND Corporation, 2005, p.194.

[927] *ibid.,* p.193.

[928] Friedberg, *op. cit*., p.130.

[929] See generally, Niall Ferguson, *Civilization*, London: Penguin Books, 2012.

[930] *ibid.,* pp.302-303.

Although China now perceives itself as a world power, there are underlying uncertainties, not least of these being whether China's Communist Party (CCP) structure can adapt to new social and political pressures. In addition, how will it choose to deal with Taiwan? In line with China's view of its place in the world, the PLA has been engaged in a concerted modernisation effort for some time, with the immediate focus being the ability to threaten Taiwan with military defeat if it attempts to break permanently from the Chinese mainland. Although economic and cultural ties between Taiwan and the China have made progress, China's military build-up continues undiminished. According to the *2010 Annual Report to Congress*: '….the PLA is developing the capability to deter Taiwan independence or influence Taiwan to settle the dispute on Beijing's terms while simultaneously attempting to deter, delay, or deny any possible U.S. support for the island in case of conflict'.[931]

China's Strategic Priorities

It may be that emerging China-US rivalry is due to misperceptions and policy issues that are relatively easy to rectify. Aaron Friedberg does not believe this is the case. Friedberg views that both the US and China have strategic objectives that threaten the other.[932] China is sure that the US wants to move China away from a one-party system towards liberal democracy. It is largely because of this that the US is seen, '….as the most serious external threat to their continued rule…[and]…they feel the need to constrict its military presence and diplomatic influence in the Western Pacific, pushing it back and ultimately displacing it as the preponderant power in East Asia'.[933] Aligned with this paradigm, China's likely strategic focus, beyond its priority of reuniting with Taiwan, will be in strengthening its presence in the South China Sea and the Indian Ocean. Andrew Erickson, in *China, the United States and 21st-Century Sea Power,* notes that Chinese analysts are concerned that the US has the power to threaten Chinese interests, including the, '…reunification of Taiwan, assertion of sovereignty over disputed islands [in the South China Sea], and ultimately some form of sea-lane security and regional maritime influence'.[934] Kissinger views China's stance over Taiwan as, '…not so much a test of Communist ideology as a demand to respect Chinese history'.[935]

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[931] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.I.

[932] Friedberg, *op. cit*., pp.1-2.

[933] *ibid*., p.2.

[934] Andrew Erickson, 'Chinese Views of America's New Maritime Strategy', in *China, the United States, and 21st Century Sea Power*, Andrew Erickson, Lyle Goldstein, and Nan Li (eds), Annapolis: Naval Institute Press, 2010, p.441.

[935] Kissinger, *op. cit.,* p.100.

According to Robert Kapan, in *The Geography of Chinese Power,* China seems to be '…developing as a great land and sea power which will at the very least eclipse Russia in Eurasia'.[936] As Geoffrey Till points out, 'Because of its growing and absolute dependence on overseas commodities, energy and markets, China, like the rest of the Asia-Pacific region has little choice but to become more maritime in its orientation'.[937]

Friedberg predicts that although China may displace the US as the World's number one economy, it is unlikely to usurp it as the dominant military power.[938] China does not publish equivalents to the US *National Security Strategy, National Defense Strategy*, or *National Military Strategy*. Rather, China uses 'white papers', speeches, and articles as the principal mechanisms with which to communicate policy and strategy. Although the transparency of China's military and security affairs has improved in recent years, including its biennial publication of *the Defense White Paper* and the 2009 launch of an official Ministry of National Defense (MND) website, it is viewed by the US as not having gone far enough.[939] Previous *Defense White Papers* have outlined a set of national interests that serve as the fundamental basis for formulating China's national defence policy. These include: '…safeguarding state sovereignty, territorial integrity and security; upholding economic development and enhancing the overall national strength; adhering to and improving the socialist system; maintaining and promoting social stability and harmony'.[940]

Crane believes that Chinese military strategists consistently emphasise the need to maintain the existence of three conditions for China to survive and prosper. In order of importance, these are - national unity, stability, and sovereignty. Chinese threat perceptions and strategic planning are largely informed by the need to maintain these three conditions. Crane also considers that the PLA's assessment of the international security

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936 Robert D. Kaplan, 'The Geography of Chinese Power: How Far Can Beijing Reach on Land and at Sea?', *Foreign Affairs* 89, no. 3, 2010, p.32.

937 Till, *op. cit.,* p.232.

938 Friedberg believes that because of a number of factors, including China's aging demographics, it will struggle to match the US militarily – see Friedberg, *op. cit.,* pp.237-244.

939 Office of the Secretary of Defense. *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.13.

940 Crane and others, *Modernizing China's Military: Opportunities and Constraints,* p.193. The latest *Defense White Paper*, published in April 2013, is shorter in content, and less formal than previous versions. It does, however, emphasise concerns with US strategy over Asia. It reiterates Japan as a security concern, while also expanding on the importance of the maritime domain as a core interest – see analysis from Kimberly Hsu, Craig Murray, and Matt Wild, *China's 2012 Defense White Paper: The Diversified Employment of China's Armed Forces',* Washington, DC: U.S.-China Economic and Security Review Commission, 3 May 2013, http://origin.www.uscc.gov/sites/default/files/Research/China%E2%80%99s%202012%20Defense%20White%20Paper--The%20Diversified%20Employment%20of%20China%E2%80%99s%20Armed%20Forces.pdf, (accessed 9 May 2013).

environment is based on the extent to which the policies and actions of other nations threaten China's ability to maintain these conditions.[941] Although China has a long history of social disobedience, incidents are ruthlessly put down. This has evolved into an indoctrination of civil obedience – the first principle is 'know your place'. The first priority is to stabilise the social order, not overturn it; social harmony is preferred over individual rights. The CCP's priority will continue to be maintaining the *status quo*.[942]

The *2010 Report to Congress* views that, '…the People's Republic of China (PRC) leaders believe the initial decades of the 21st century as a "strategic window of opportunity," and will be conducive to China's rise to regional pre-eminence and global influence'.[943] The report also assesses that, although China's leaders continue to support the process of reform, there is a growing recognition that the process of change has forced a number of dilemmas. Although these reforms have enabled China to experience rapid growth, they have also led to substantial challenges, particularly to internal stability. Significantly, the report assesses that these conclusions have led China's leaders to determine that they should focus on managing or exploiting external tensions, especially with the US and other major powers, to maintain an environment conducive to China's growth, at least until 2020. The report judges that China could be deterred from a nonviolent course.[944] The CCP are aware that once begun, unrest could be difficult to control and could easily turn against the state. Additionally, unexpected increases in resource demand, and access to these resources, could affect China's strategic viewpoint, and might force it to re-examine its resource priorities.[945] While the report does seem to offer a relatively gloomy picture, there are more moderate views. China's current position could be viewed as an attempt to sustain regional stability and to reassure its neighbours, as opposed to weakening the US's position in Asia.[946] That said, there is certainly the acknowledgement within China's leadership that the biggest external obstacle to achieving a true great power status, is the US.[947]

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[941] Crane and others, *op. cit*., p.192.

[942] There is a growing awareness within China that social reforms are necessary. In 2008, for example, Hu Jintao, proclaimed a doctrine of 'harmonious society', with the aim of mitigating the inequalities of growth. It is increasingly recognised that China risks significant domestic instability, if democratic reforms are not embraced – see Fenby, *The Penguin History of Modern China*, pp.671-672.

[943] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.15.

[944] *ibid.*

[945] *ibid.*

[946] Robert Sutter, 'China and US Interests: Opportunities and Challenges', in *US-China-EU Relations: Managing the New World Order*, Robert Ross, Oystein Tunsjo, and Zhang Tuosheng (eds), Abingdon: Routledge, 2010, p.100.

[947] Friedberg, *op. cit*., p.142.

The possibility of a military conflict with Taiwan and US military intervention remain China's most pressing long-term military concern. A potential conflict will drive China's military modernisation as long as China's leaders judge that the permanent loss of Taiwan could seriously undermine the regime's political legitimacy and hold on power.[948] Coping with these forces will be fundamental to the development of China as a world superpower. Within China itself, there are some strident views. As an example, *The Sunday Times* has highlighted a more bellicose trend among the Chinese military, in particular. Michael Sheridan writes: '…army and navy officers [predict] a military showdown, [with] political leaders calling for China to sell arms to America's foes. The trigger for their fury was Obama's decision to sell $6.4 billion worth of weapons to Taiwan…'.[949]

Despite an increase in rhetoric from within China, some analysts believe the chance of war between China and the US is remote, as the Chinese military threat to the US is only indirect. Jacqueline Newmyer, writing in *Orbis*, believes that China's grand strategy today seeks, '…to prevent the encirclement of China while encircling prospective enemies, with the aim of creating a disposition of power so favorable to the PRC that it will not actually have to use force to secure its interests'.[950] Rather than fight the US outright, the Chinese may be seeking to influence US behaviour precisely to avoid a confrontation. Nonetheless, the US is required by its own laws to defend Taiwan. While the provision of military equipment is one part of the Taiwan Relations Act, the act also has another fundamental obligation, that is: '…to maintain the capacity of the [US] to resist any resort to force or other forms of coercion that would jeopardize the security, of the social or economic system, of the people on Taiwan'.[951]

Even if the US stood by its obligations, could it actually defend Taiwan? Stillion and Perdue believe that by the year 2020, the US will no longer be able to defend Taiwan from a Chinese attack. They emphasises the air battle - China is just 100 miles away from Taiwan, whereas the US must project military power from vast distances, with more limited access to foreign bases than it had during the Cold War. This strategy is designed not only to deny US Navy entry into Chinese areas of interest, but also to keep US forces away

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[948] Office of the Secretary of Defense. *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.16.

[949] Michael Sheridan, 'China's Hawks Demand Cold War on the US', *The Sunday Times*, 7 May 2010, p.32.

[950] Jacqueline Newmyer, 'Oil, Arms, and Influence: The Indirect Strategy Behind Chinese Military Modernization', *Orbis* 53, no. 2, Spring 2009, p.207.

[951] Mark Stokes, *op. cit.*, p.36. On April 10, 1979, President Jimmy Carter signed into law the Taiwan Relations Act (TRA). The TRA provides the legal basis for the unofficial relationship between the US and Taiwan, and commits the US in assisting Taiwan maintain its defensive capability - see Taiwan Relations Act: United States Code Title 22 Chapter 48 Sections 3301 - 3316 - Enacted 10 April 1979, http://www.taiwandocuments.org/tra01.htm, (accessed 25 May 2008).

generally.[952] If the US were to abandon Taiwan to China, then Japan, South Korea, the Philippines, Australia, and other US allies in the Pacific, as well as India, will begin to doubt the strength of the US's obligations. According to Robert Kaplan, this could ultimately encourage these states to move nearer to China, allowing the emergence of a China with true supremacy in the Pacific Rim, and further afield.[953] The subsequent fallout would change the balance of power in the region, with the associated ramifications for the rest of the world.

Economic Development

It is generally acknowledged that China is now the No 2 economic power, after the US, having overtaken Japan in 2010.[954] A nation's power is more than its economic clout, however. China's use of its own method for calculating a nation's power, CNP, has varied somewhat in its consistency. There are two contending scientific teams calculating CNP: military, and civilian. The Academy of Military Science (AMS) analysis contradicts the Chinese Academy of Social Sciences (CASS), with AMS assessing that China's CNP score will equal the US, by 2020, while CASS consider that China's CNP score will be half that of the US, by 2020, with Japan's CNP 20% higher than the US.[955] In the mid-1980s, Deng Xiaoping, China's leader at the time, stressed that it was important to calculate future trends in CNP, in order to guide China's reforms; these CNP calculations include economics, science, defence, and other factors. Although calculating CNP was developed in 1984, Chinese authors rationalise the use of CNP theory stating that it originally stems from ancient Chinese strategists. Chinese analysts place great store on CNP scores, considering them an important tool in helping to identify five trends: 'The status hierarchy in world politics…The power of potential rivals and potential partners… Who will best exploit the Revolution in Military Affairs?... Which side will win a war?...The trend toward world multi-polarity and US decline'.[956] Some Chinese commentators assess that although the US's CNP decline will be relative, it will be actual, and it will be transformed from a superpower to a common power.[957]

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[952] Stillion and Perdue, *op. cit.*, PPF.8, 9, and 14.

[953] Kaplan, 'The Geography of Chinese Power: How Far Can Beijing Reach on Land and at Sea?', p.36.

[954] Frida Ghitis, 'World Citizen: Will China Challenge U.S. as a Global Superpower?', *World Politics Review*, 21 October 2010, http://www.worldpoliticsreview.com/articles/6787/world-citizen-will-china-challenge-u-s-as-global-superpower, (accessed 25 October 2010).

[955] Pillsbury, *op. cit*., pp.317-318.

[956] *ibid.,* p.317.

[957] *ibid.,* pp.85-88.

Western forums make their own analysis – with most agreeing that it is only a matter of time before China overtakes the US as the No 1 economic power, as discussed earlier. There are, of course, contrary views. Professor Joseph Nye, an adviser to various US administrations, believes that the image of the US's absolute decline is false, but its relative decline is the same as closing the gap. Nye does not believe China will overtake the US, and that the US has time to adapt strategy to mitigate China's rise.[958] James Mackintosh, writing in the *Financial Times*, views that although the economic consensus believes that China will keep expanding, to surpass the US in dollar terms sometime in the next 40 years, research predicts that growth will fall, with many potential triggers for a slowdown, such as a shortage of housing, leading to a housing bubble, and runaway food inflation.[959] Aaron Friedberg also believes China's growth will slow down:

> After decades of good fortune and nearly uninterrupted growth, China may yet experience a sharp economic crisis from which it will have great difficulty recovering. If that happens, the remarkable progress of recent decades could give way to social unrest and political upheaval, and the "Chinese century" that so many have predicted could be over before it really has a chance to get started.[960]

Even the Chinese Prime Minister in 2010, Wen Jiabao, admitted that the economy was, 'unstable, unbalanced, uncoordinated, and ultimately unsustainable'.[961] There are, however, those that argue that China's economy is resilient, and as long as it continues to manage its power and water supplies, this will, aligned with its international reserves and internal financial wealth, allow it to continue to further expand its GDP and GPD per capita.[962] Justin Yifu Lin, Chief Economist of the World Bank in 2011, believes '…China has the potential of maintaining an 8% annual growth rate for another two decades'.[963] This does not mean it will not slow down. Paradoxically, slowdown in economic growth in China will affect the economic recovery of other countries, including Western states.

China's rapid economic growth will allow it to fulfil its international ambitions, if internal pressures do not force it to deviate from its objectives. John Mearsheiner, in *The Tragedy*

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958 See Professor Joseph Nye, *The Future of Power,* pp.6-7.

959 James Mackintosh, 'History Shows China Slowdown Due', *Finanicial Times*, 24 January 2011, p.28.

960 Friedberg, *op. cit*., p.35.

961 Globalpost Editorial, 'East Asia Showdown: China and Japan and a Failure of Diplomacy', *Globalpost* (2010). http://www.globalpost.com/dispatch/china/100920/japan-clash-diplomacy, (accessed 14 July 2010). p. 12. Robert Kaplan believes that, although China's GDP growth rates cannot continue at its present rate, because of its geography and inherent structures, it will not stop China's progress – see, Robert Kaplan, *The Revenge of Geography*, New York: Random House, 2012, pp.197-200.

962 Rajah Rasiah, Zhang Miao, and Kong Xin Xin, 'Can China's Miraculous Economic Growth Continue?', *Journal of Contemporary Asia*, 2012, p.16. There is an ironic view that China will need to rely on the US for the protection of its SLOC for energy supplies - see Erica Strecker Downs, *China's Quest for Energy Security*, Santa Monica, CA: RAND Corporation, 2000, pp.43-52.

963 Justin Yifu Lin, 'China and the Global Economy', *China Economic Journal* 4, no. 1, 2011, p.11.

of Great Power Politics, believes China has the capacity to be significantly more powerful than the US, viewing:

> Not only would China be much wealthier than any of its Asian rivals...but its huge population advantage would allow it to build a far more powerful army than either Japan or Russia could. China would also have the resources to acquire an impressive nuclear arsenal. North East Asia...would be a far more dangerous place than it is now. China, like all previous potential hegemons, would be strongly inclined to become a real hegemony, and all its rivals, including the United States, would encircle China to try to keep it from expanding.[964]

This view may seem somewhat radical, yet Mearsheimer is by no means the only international relations analyst to raise concerns over China's rapidly expanding economy, aligned with its strategic intentions. A number of US analysts and policymakers have also raised apprehensions about the potential for China to mount a serious strategic challenge to the US in Asia, especially in the Western Pacific, during the course of the next two decades.[965] These concerns are based on China's expanding economy and growing military capabilities. The rapid economic growth of the past three decades has dramatically increased the resources the Chinese government has available to devote to military spending. Recent double-digit percentage increases in officially reported defence budgets indicate the degree to which China's growing economic base has permitted the Chinese government to increase the resources it expends on the military.[966] The real growth in defence spending is considerably more.[967] The economy has not only enjoyed very rapid rates of growth over the past few decades, it has also benefited from large inflows of direct foreign investment, massive imports of modern equipment and machinery, and significant improvements in China's educational system and the return of Chinese students from studying abroad. All have contributed to the creation of a number of modern industrial sectors, especially in information technology.[968] This technological and intellectual evolution and capacity will be fundamental to China's continued economic expansion and military transformation.

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[964] Alex Callinicos, "The Grand Strategy of the American Empire," *International Socialism Journal*, no. 97 (Winter 2002), http://pubs.socialistreviewindex.org.uk/isj97/callinicos.htm, (accessed 27 May 2009).

[965] Crane and others, *op. cit*., p.1.

[966] *ibid.*

[967] The US DoD estimates that China's military-related expenditure for 2012 was between $135 billion to $215 billion, whereas, China's official military budget was $106.7 billion – see Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2013',* Washington, DC: Department of Defense, 2013, http://www.defense.gov/pubs/2013_China_Report_FINAL.pdf, (accessed 12 May 2013), pp.45-46.

[968] This economic and technological growth is largely down to the reengagement by the US with China from the 1989, and the desire to open up trade connections and invest capital – see Friedberg, *op. cit.*, pp.109-110.

String of Pearls, Sea Lines of Communications and the South China Sea

China's position *vis-à-vis* Taiwan and the South China Sea is becoming increasingly confrontational and intransigent. With China's economy growing, it is likely that China will continue to use its economic and diplomatic muscle to expand its influence in the Asia-Pacific region, particularly, in the South China Sea and the Indian Ocean. These represent key Sea Lines of Communication (SLOC) for China's energy supply – the majority of China's crude oil imports transit the Strait of Malacca from the Indian Ocean. This strategic focus is likely to create friction between China and India, at the very least. Robert Kaplan believes: 'China seeks domination of the South China Sea to be the dominant power in much of the Eastern Hemisphere…'.[969] Kaplan goes further, '…the South China Sea is a vital route for much of Asia's commercial traffic and energy needs. The US and other nations consider it an international passageway. China calls it a "core interest"'.[970] If not over Taiwan, then it is the importance that China places on its perceived right of hegemony over the South China Seas that will feature in the coming years. This sea connects Southeast Asian states with the Western Pacific, acting as the conduit for global sea trade. More than half the world's annual merchant fleet tonnage passes through the Straits of Malacca, Sunda, Lombok, and Makassar. As much as 80% of China's imported oil and gas has to pass through the Strait of Malacca.[971] It is likely that China will continue to import 60% of its oil, rising to at least 70% by 2035, keeping its import routes crucial.[972] There is little doubt proven oil reserves of seven billion barrels, and an estimated 900 trillion cubic feet of natural gas, are factors swaying China's position.[973] China's own position in the Western Pacific emphasises its prominence when looking towards the South China Sea. China looks south towards Taiwan, the Philippines, Malaysia and Indonesia, the Malay Peninsula divided between Malaysia and Thailand, and Vietnam. Kaplan views '…the South China Sea is an obvious arena for the projection of Chinese power'.[974]

Despite China's desire to return Taiwan to the fold, its foreign policy is also currently turned more to engagement and involvement with its regional neighbours. With an Indian naval base on the Andaman and Nicobar islands, and a large US navy presence in the region,

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[969] Robert D. Kaplan, 'The South China Sea Is the Future of Conflict,', *Foreign Policy*, 15 August 2011, http://www.foreignpolicy.com/articles/2011/08/15/the_south_china_sea_is_the_future_of_conflict, (accessed 18 November 2011).

[970] *ibid.*

[971] Office of the Secretary of Defense. *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.17.

[972] Moyo, *op. cit.,*. pp.144-145.

[973] Kaplan, 'The South China Sea is the Future of Conflict', *op. cit.*

[974] *ibid.*

China has long feared that its trade and energy routes are vulnerable to blockade. In response, China has created its ‘String of Pearls’ strategy.[975] This is China’s desire to increase its geopolitical influence through efforts to increase access to ports and airfields, develop special diplomatic relationships, and modernise military forces extending from the South China Sea through the Strait of Malacca, across the Indian Ocean, and on to the Arabian Gulf. Each ‘pearl’ in the ‘String of Pearls’ is an interconnection of Chinese geopolitical impact and military presence.[976] A number of different types of facilities, in a variety of locations, make up the ‘String of Pearls’. Hainan Island, with recently upgraded military facilities , a container shipping facility in Chittagong, Bangladesh, the construction of a deep water port in Sittwe, Myanmar, and the construction of a navy base in Gwadar, Pakistan – are all examples of ‘pearls’. The ‘pearls’ extend from the coast of mainland China through the littorals of the South China Sea, the Strait of Malacca, across the Indian Ocean, and those of the Arabian Sea and Persian Gulf. China will continue to build strategic relationships and develop a capability to establish a forward presence along the SLOC connecting China to the Middle East.[977]

Projects at strategic points across the Indian Ocean will allow China to extend its growing naval strength well beyond its traditional coastal waters.[978] In addition, China plans to build thousands of miles of new railways to connect the southern Chinese city of Kunming with ports across Myanmar and South East Asia. Not only will China's partnership with Myanmar help safeguard its own energy supply, but it will also give China a key strategic advantage over Japan and South Korea, who also rely on the Strait of Malacca for part of their energy supplies.[979] See Figure 2 below.

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[975] Malcolm Moore, 'China Ends Its Oil Fear with Port Deal', *The Daily Telegraph*, 15 January 2011, p.23.

[976] C. J. Pehrson, *String of Pearls: Meeting the Challenge of China's Rising Power across the Asian Littoral',* Strategic Studies Institute United States Army War College, 2006, http://www.strategicstudiesinstitute.army.mil/pubs/publication-search-results.cfm?criteria=string+of+pearls, (accessed 26 March 2009), p.3

[977] *ibid.*

[978] David Blair, 'China Rising over the East Again', *The Daily Telegraph*, 20 May 2009, p.17.

[979] Moore, *op. cit*., p.23.

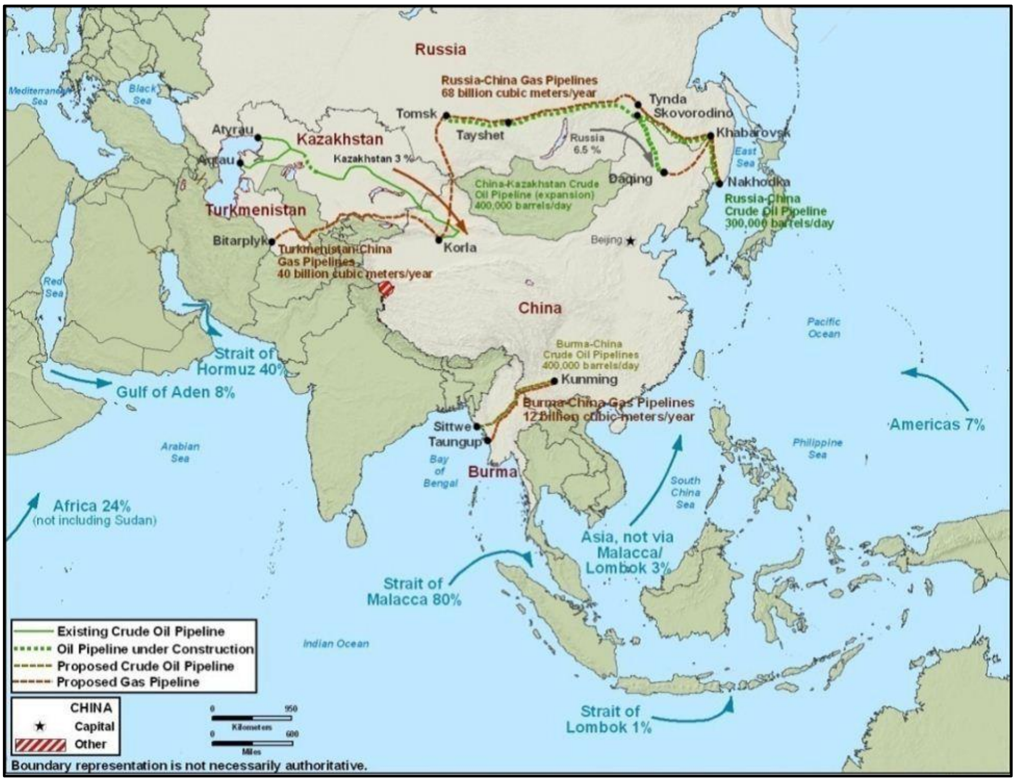

Figure 2: China's import transit routes/critical chokepoints and proposed/under construction SLOC bypass routes.[980]

China is not limiting itself to the Asia-Pacific Region, with many African countries having received large inputs of Chinese funding. China's policy of not linking trade, aid, and investment to political reform or human rights issues has paid huge dividends thus far.[981] In less than a decade, it has created a presence across the entire African continent, ensuring a steady supply of much needed raw materials. In Angola, the Chinese have built roads, upgraded ports and transformed railways. They are also deeply involved in new construction projects in Ethiopia and Kenya.[982] China has similarly used its surplus of foreign currency reserves to cement new alliances and finance cut-rate loans and commercial lines of credit. There is only one condition: any money provided must be used to pay Chinese companies and buy Chinese goods that flood the continent's street markets.[983]

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980 Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.21.

981 China is not the only state to use economic power to entice access to natural resources, but it does so, largely without good governance or human right conditions attached - see Nye, *The Future of Powe*r, pp.76-77.

982 Jonathan Clayton, 'China Tightens Its Grip on Africa with $4.4bn Lifeline for Massacre Junta', *The Times*, 13 October 2009, p.33.

983 *ibid*.

Will African and other countries presently appreciating this apparent Chinese largesse always be as accommodating? Does this doctrine of a 'String of Pearls' work to China's advantage? Time will tell, but China can afford to play the long game. This strategy may be seen as two-fold: firstly, to extend its economic power and exposure to markets, and secondly, to impress upon regional neighbours that it is not a threat to their well-being.

China's Military Build-up

The smaller states in the Western Pacific region accept that there is little they can do to counter Chinese regional aspirations and military capabilities. However, in some cases, particularly Russia, Japan and India, there is likely to be a more robust response, including a potential military build-up to counter China's burgeoning claims. China's recent test flight of a 'stealth fighter', the J-20, came as somewhat of a shock to Western intelligence agencies.[984] The speed at which China has reached this stage of development is impressive. China is not in the same league as the US in this type of capability, but is very likely to edge closer to Western concepts and capabilities in the coming epochs.[985] New technologies do not necessarily make a nation's armed services more efficient or capable; however, when aligned with robust doctrine and training, then improvements will naturally emerge. The mere fact that China is attempting to field an aircraft such as the J-20 is, perhaps, good news for the US administration, as it focuses on the potential threat. US intelligence apparently failed to spot its rapid development.[986] This is hard to believe, but is convenient, nonetheless. Ultimately, this type of development will drive other countries to develop counters. Russia and India are spending billions of dollars in upgrading their armed forces, India being a major importer of Russian military equipment, particularly fighter aircraft. Previously highlighted, both countries are jointly developing a 5th-generation fighter, the PAK-FA, sometimes referred to as the T-50, which is seen as being as a counter to the F-22; it is planned to be in operational service by 2020.[987] The US is refusing to export the F-22 to any foreign state, no matter how friendly. Japan, while restricted by post World War II treaty obligations to remain a 'defence force', is considering developing its own sixth-generation fighter as a counter to the J-20.[988] It seems that Japan

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984 For a view on the J-20, see Dr Ayse Abdullah, (ed),*The Military Balance*, London: Routledge, 2012, p.212.

985 *ibid.,* p.205.

986 Michael Evans, 'US 'Failed to Spot China's Rapid Advance in Missiles and Jets'', *The Times*, 10 January 2011, http://www.thetimes.co.uk/tto/news/world/asia/article2868526.ece, (accessed 12 January 2011).

987 Alexey Drujinin, 'Russian-Indian Second Prototype T-50 Fighter to Fly in 2011', 20 December 2010, *RIANOVOSTI*, http://en.rian.ru/russia/20101220/161853847.html, (accessed 3 January 2011).

988 Perrett, *op. cit.*, p.29.

views its lack of a 5th-generation fighter as a significant disadvantage. Towards the end of 2011 Japan announced its intention to buy 42 F-35 JSF.[989] It is likely that Japan has had to settle for what it views as the second best option. This may or may not be correct, however, the acquisition of the F-35 will allow Japan to 'learn' the technology available, thus adapting it to its own indigenous developments.

China's stance on Taiwan and the South China Seas, and its military build-up, is causing other Western Pacific rim states to reconsider their military requirements. Andrew Erickson from the US Naval War College has argued that China's ASBM programme may produce pressure in Washington and Moscow to revise or abandon the International Nuclear Federation treaty, and that other nations, such as Japan, may feel compelled to develop similar capabilities as well.[990] Richard Lloyd Parry, in *The Times,* writes that tensions have recently flared between China and Japan when:

> .…Japan announced that it would redeploy its armed forces in a calculated response to China's growing military power. Beijing reacted angrily after Tokyo announced that a new defence policy would shift its forces to protect strategic islands claimed by China. The National Defence Programme Guidelines, approved yesterday by the Cabinet…, represents the biggest shift in Japan's defence thinking since the end of the Cold War, and explicitly changes the emphasis from the threat formerly posed by Russia to the growing military ambitions of China.[991]

Increased investment in hardware and training by Beijing is designed to dissuade the US from interfering in problems such as the long-running dispute over Taiwan. According to Jonathan Holslag, author of *Trapped Giant: China's Military Rise,* although the US has been the dominate power in the Western Pacific since World War II: 'After the demise of the Soviet Union, China is emerging as the second power that might alter the military balance in a way that fundamentally reshapes the regional security order'.[992]

According to the US Office of the Secretary of Defense, 'The PLA seeks the capability to deter Taiwan Independence and influence Taiwan to settle the dispute on Beijing's terms. In pursuit of this objective, Beijing is developing capabilities intended to deter, delay, or deny possible U.S. support for the island in the event of a conflict'.[993] This view may be

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[989] Bob Cox, 'Japan to Buy 42 F-35 Joint Strike Fighters', *Star-Telegram*, 20 December 2011, http://www.star-telegram.com/2011/12/19/3606476/japan-to-buy-42-f-35-joint-strike.html, (accessed 28 December 2011).

[990] Mark Stokes, *op. cit.,* p.37.

[991] Richard Lloyd Parry, 'China Fury at Japanese Military Shift', *The Times*, 18 December 2010, http://www.thetimes.co.uk/tto/news/world/asia/article2848040.ece, (accessed 18 December 2010).

[992] Jonathan Holslag, *Trapped Giant: China's Military Rise*, Abingdon: Routledge, 2010, p.8.

[993] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2011,* Washington, DC: Department of Defense, http://www.defense.gov/pubs/pdfs/2011_CMPR_Final.pdf (accessed 11 November 2012), p.1. See also, Zalmay Khalilzad, 'Congage China', in *Project Airforce: Issue Paper*, Santa Monica: RAND Corporation, 1999, pp.2-3.

correct; however, the scale and strategic reach of capabilities being developed by China appears well in excess of what would be required to defeat Taiwan and deter US intervention. Its long-term aim to achieve a dominant position in Asia would allow China to add a coercive element to its extant policy of using ‘soft power’ to exert influence over regional nations.

The PLA has made modest improvements in the transparency of China’s military and security affairs, although it is nowhere near the level required to allow other states to adequately analyse its strategic intentions, in apparent denial of what that means for other states’ strategy: it is in effect doubling expenditure on military capabilities. Many doubts remain regarding how China will use its expanding capabilities; it is certainly not adequate to claim that Taiwan is the sole focus of its military ambitions.[994] This limited transparency in its military and security affairs has only enhanced uncertainty and increased the potential for misunderstanding and miscalculation.[995] The US, Japan, and others, have repeatedly called on China to be more overt with its defence plans.

Richard Weitz, in *Strategic Posture Review,* notes that foreign analysts believe that official Chinese budget figures exclude spending on nuclear weapons, purchases of foreign weapons, and military research and development. For this reason, analysts generally double or triple the official Chinese defence spending figures.[996] The *2010 Report to Congress* states: ‘…that much more could be said by China about its military investments, the strategy and intentions shaping those investment choices, and the military capabilities it is developing’.[997] The graph below details the US official interpretation of China’s defence budget, up to 2009, which essentially believes that the real expenditure is twice that acknowledged by China.

[994] Editorial, 'Arms and Openess,' *The Times,* (12 January 2011). http://www.thetimes.co.uk/tto/opinion/leaders/article2871311.ece?lightbox=false, (accessed 13 January 2011).

[995] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.1.

[996] Richard Weitz, 'Strategic Posture Review: China 2010', World Politics Review, 2010, pp.2-3.

[997] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.13.

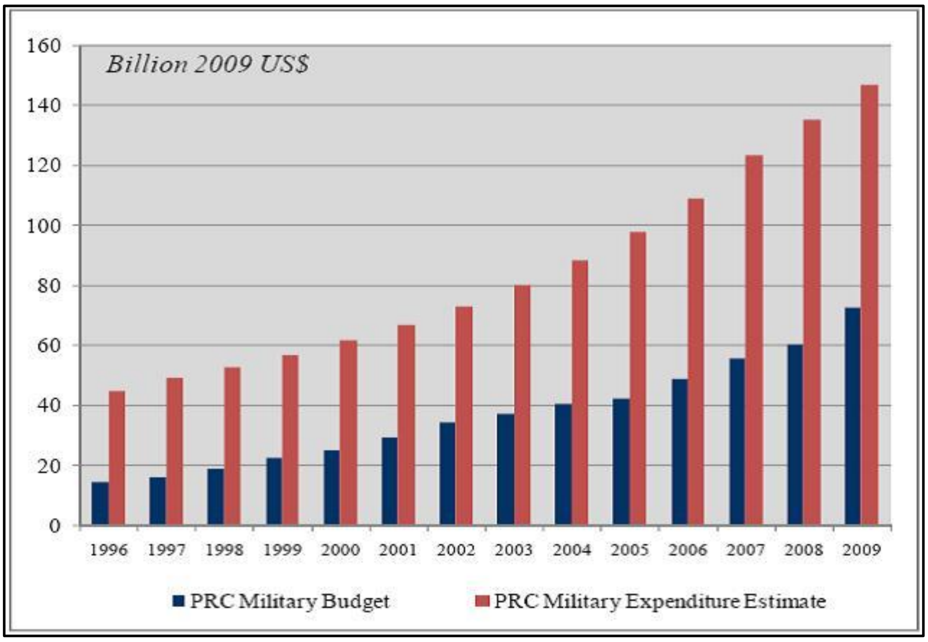

Figure 3: China's annual real GDP and military budget growth: 1996 – 2009[998]

Part of the difficulty is assessing the size of China's defence budget, just as it was in estimating the Soviet's military spending during the Cold War. China's annual defence budget supposedly increased in 2010 by 6.0% to US $78.7 billion.[999] This is still only 9% of the American defence budget, which was US $693.6 billion in 2010.[1000] China's official defence budget increased by 9.1%, to US $90.2 billion for 2011.[1001] Defence analysts view these increases, and recent confrontation between the regions' military over territorial claims in the South China Sea, as indicative of a China prepared to use force, if necessary.[1002]

Increasing national wealth has allowed China to pursue the single largest sustained arms buying spree observed since the Soviet build-up in the last decade of the Cold War. However, China's military faces a number of constraints, not least, its ability to acquire the equipment and facilities it desires.[1003] Constraints faced also include the deficiencies of China's own defence industry and external restrictions on imports of more capable equipment from foreign suppliers.[1004] All that said, unlike the Soviet build-up, which

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998 *ibid*., p. 42.

999 Official US figures give this as $111.1 billion, see Abdullah, *The Military Balance: 2013*, p.256.

1000 Abdullah, *The Military Balance: 2012*, p.467.

1001 Official US figures give this as $136.7 billion, see Abdullah, *The Military Balance: 2013*, p.256.

1002 Leo Lewis, 'Eyes of the World on Beijing as Military Budget Gets 12% Boost', *The Times*, 5 March 2011, p.23.

1003 Crane and others, *op. cit*., p.3.

1004 *ibid.*, pp.3-4.

effectively bankrupted its economy, China's build-up should be sustainable if its economy continues to grow at a pace allowing it to spend revenues that would not otherwise be required for domestic purposes. Nonetheless, as already discussed, a number of effects will need to align. First, the economy will have to continue to grow. Second, the government will have to be able to extract revenues for military expenditures. Third, balancing competing pressures for social welfare and education, and more public investment in infrastructure, against increased military spending, will be difficult. Last, not least, China's defence industries will have to be able to produce the weapon systems that it would need to seriously challenge US forces.[1005] Progress is being made in China's ability to manufacture its own weapon systems, nonetheless. A RAND Corporation report cites the possibility, '….that China may be more advanced [than the US] technology and militarily in 2020'.[1006] This may be a somewhat pessimistic view, with more current analysis giving different timescales. For example, Tai Ming Cheung from the US Institute on Global Conflict and Cooperation, cites a report from China's International Institute of Management Development, giving the view that China will reach science and technology parity with the US between 2040 and 2050.[1007] It is possible that China may develop the technological wherewithal, at least in some industrial branches, to produce comparable (to the West) modern weaponry.

Whatever the case, the military's ability to acquire the equipment and services it needs will require great effort. A major factor is that the Chinese military has to contend with competitive markets for management and leadership talent, and restricted sources of supply for advanced weaponry; it also suffers from severe weaknesses in integrating weapons systems.[1008] Recent concerns by Russia over Chinese production of aircraft engines, reverse engineered from Russian-supplied engines, for its indigenously produced J-11 fighter, highlight the reluctance of some countries, particularly Russia, to allow China unfettered access to their technology.[1009] Ultimately, if China's economy continues to modernise over the coming decades, its military equipment and weapons producers are likely to have access to domestically produced components to construct the military

[1005] *ibid.*, p.1.

[1006] Roger Cliff, *The Military Potential of China's Commercial Technology*, Santa Monica, CA: RAND Corporation, 2001, p.xv.

[1007] Cheung, *op. cit*., Section 1; p. 19.

[1008] Crane and others, *op. cit*., p.3.

[1009] The Shenyang J-11 (Jianji-11 or Jian-11) is the Chinese copy of the Sukhoi Su-27 (NATO reporting name: Flanker) air-superiority fighter built by the Shenyang Aircraft Corporation. The basic variant J-11, built using Russian-supplied kits, is identical to the Su-27SK. Future productions of the J-11 will also be powered by the indigenous FWS-10A 'Taihang' turbofan jet engine – see Editorial, 'Jian-11 Multirole Fighter Aircraft', *sinodefence.com*, 20 February 2009, http://www.sinodefence.com/airforce/fighter/j11.asp, (accessed 24 September 2010).

equipment and systems needed to narrow the capabilities gap with the US.[1010] Notwithstanding domestic and other internal pressures, viewed holistically, this will have consequences for international relations in the coming decades.

Perhaps one of the most important intangibles, when assessing a state's capability to field a potent military force, is the quality of its personnel. It is not a given that the possession of state-of-the-art weapons translates into the ability to achieve superiority over an adversary. History has illustrated that those forces that have achieved a high level of efficiency through training will beat or hold off an opponent, even when evenly matched with equipment and numbers of personnel.[1011] The morale and *esprit de corps* of a force should also not be underestimated, both of which can be difficult to establish and maintain. Whether this will be a decisive factor in future warfare is an important point. Will mass outweigh quality and training? This is not to say that the PLA cannot motivate its personnel, but the Chinese people, as a whole, will also need to be encouraged towards a similar mind-set.

The First and Second Island Chains

Kaplan believes that in the coming decades it is likely that China will project its power abroad, principally through its navy.[1012] China's horizons have broadened; it acknowledges that to continue its prosperity, maintain its SLOC and supplies of energy, it can no longer continue to be 'land-centric' and wait for an adversary to come to it. It must be able to fend off a possible challenger as far as Japan to the east, and the Spratly Islands to the south – the 'First Island Chain'. PRC military theorists conceive of two island chains as forming a geographical basis for China's maritime defensive boundary. The precise frontiers of these chains have never been officially defined by the Chinese government, and are subject to some conjecture. For example, Kaplan states that the 'First Island Chain' consists of the Korean Peninsula, the Kuril Islands, Japan, Taiwan, the Philippines, Indonesia and Australia.[1013] Another account states China's 'green water' extends eastward in the Pacific Ocean out to the 'First Island Chain', which is formed by the Aleutians, the Kuriles, Japan's archipelago, the Ryukyus, Taiwan, the Philippines, and Borneo. Further eastward is referred to as 'blue water' extending to the 'Second Island Chain' running from the north at the Bonin Islands and moving southward through the Marianas, Guam, and the Caroline

[1010] Crane and others, *op. cit.*, pp.1-2.

[1011] For example, see Steven Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle*, Princeton, NJ: Princeton University Press, 2004, pp.68-69.

[1012] Kaplan, 'The Geography of Chinese Power', p.33.

[1013] *ibid.*

Islands.[1014] Whatever is the real Chinese interpretation, it remains an extant part of China's policy to push US influence beyond the 'First Island Chain', at the very least. Initially, if it was deemed necessary, China would seek to be able to take control over the Yellow Sea, the East China Sea and the South China Sea, all of which are located within the 'First Island Chain' of the Pacific Ocean, including the Philippines and the Ryukyu Islands.[1015]

Taiwan and the South China Sea

The China/Taiwan dynamic is, perhaps, the most important potential flashpoint in the Western Pacific. Taiwan's paramount goal is to preserve its *de facto* independence and reinforce its separate identity, which allows it to govern itself autonomously; an acceptable condition in which neither sides risks cross-strait relations by pressing for independence or reunification. This issue largely defines Taiwan's political spectrum. China's fears about Taiwanese independence and possible US intervention are the most relevant to the PLA's current planning and procurement.[1016] Since the end of the 1990s, PLA reform, modernisation, procurement, and training have been predominantly focused on preparing for a conflict over Taiwan. Taiwan is at the top of the PLA's list of possible conflicts. In this context, US policies on the Taiwan question are of immediate concern to Chinese defence planners. According to Crane and others, in *Modernizing China's Military: Opportunities and Constraints:*

> The leaders of the People's Republic of China are committed to ensuring the reunification of Taiwan on their terms; U.S. policies are seen as directly preventing this outcome. Some Chinese military planners fear that the United States seeks to keep Taiwan apart from the mainland to use it as a strategic point in Asia to limit the growth of China's regional influence.[1017]

Specifically, PLA strategists perceive US arms sales to Taiwan and bilateral military agreements as part of an effort to keep China permanently divided. Most Chinese and Western analysts presume that the US would intervene in a conflict, unless Taiwan declared independence. As a result, much of the PLA's modernisation has been focused not only on fighting Taiwanese forces, but on also fighting US forces if a conflict were to

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[1014] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, p.23.

[1015] For an excellent background to China's claims in the Western Pacific, and international reaction to these, particularly the US, see David Lai, *The United States and China in Power Transition,* Carlisle, PA: U.S. War College Strategic Studies Institute, 2011, http://www.strategicstudiesinstitute.army.mil/pdffiles/PUB1093.pdf, (accessed 23 February 2011), pp.117-152.

[1016] See Holslag, *op. cit*., pp.126-129.

[1017] Crane and others, *op. cit.,* p.194.

erupt.[1018] US military build-up in the Pacific cannot but affect China's response. An example is the new prominence and expansion of US Pacific Command (PACOM). PACOM is the largest of six regional commands; its emphasis is on improved technologies and infrastructure in its bases in Hawaii, Guam and Japan, which require a huge investment, all of which concerns China.[1019]

Over the past few years, China has amassed enormous amounts of US government debt. Such economic pressure has led to calls to reassess the US - Taiwan relationship. A 2011 article in *Foreign Affairs* called on the US to reappraise its promise to defend Taiwan in order to maintain mutual peace and avoid a negative arms race spiral.[1020] The *New York Times* published an editorial calling to stop arms sales to Taiwan, and to abandon the defence of the island in exchange for China dropping its US debt and save the US economy.[1021] US authorities immediately came out to reject this recommendation as naive. But does it have merit? There is a perception within Taiwan that the US is indeed contemplating a radical reappraisal of its position over Taiwan. With cuts in its military budget, as well the rise of China's maritime strike capabilities, the US has gradually started to withdraw its first line of defence from Asia in order to avoid a possible confrontation. Domestic protests in Japan have led to the US transferring half of its personnel to Guam in 2011, while a complete withdrawal from Japan is possible in the future. At the same time, the US plans to station troops in northern Australia.[1022] According to the *Taiwan News,* the US plans to use control over the South China Sea to successfully close off the Strait of Malacca during wartime as well as the sea route between the Indian Ocean and the Pacific.[1023] Undoubtedly, this would exert pressure on the oil supply route between the Middle East and China. What effect will this have on the balance of power in the region? If the US does indeed intent to change its strategy and move its strategic line to the Second Island Chain, thereby extending the distance at which the PLA is required to operate, will this mean it is abdicating its responsibilities under the TRA act?

China has a long history of employing ambiguous tactics and nefarious means to conceal the true reasons behind its military revolution and to advance its aspirations in the Asian-

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[1018] *ibid.*

[1019] Holslag, *op. cit*., pp.30-38.

[1020] Charles Glaser, 'Will China's Rise Lead to War?', *Foreign Affairs* 90, no. 2, 2011, pp.80-91.

[1021] Paul V. Kane, 'To Save Our Economy, Ditch Taiwan', *The New York Times*, 10 November 2011, http://www.nytimes.com/2011/11/11/opinion/to-save-our-economy-ditch-taiwan.html, (accessed 3 August 2012).

[1022] Abdullah, *The Military Balance: 2012*, p.207.

[1023] Editorial, 'China, U.S., Japan, Taiwan - Four Nations Tilting out of Balance', *Taiwan News,* http://www.taiwannews.com.tw/etn/news_content.php?id=1780306, (accessed 14 December 2011).

Pacific region. In the 1990s, as China accumulated and intermittently fired ballistic missiles across the Taiwan Strait to intimidate Taiwan, it assured the world that its military build-up served only benign ends, and that it sought peaceful reunification with Taiwan.[1024] However, this stance was not universally accepted, and in response to China's 1996 firings and military exercises near Taiwan, the US deployed the USS Nimitz CSG, which the Chinese were unable to counter at the time. This US deployment produced a strong sense of resentment, and is the principal reason for Chinese efforts to develop ASBM, with the aim of preventing similar US carrier operations in the future.[1025] China desires the ability to prevent effective US intervention in the event of a future Taiwan Strait confrontation and to constrain its influence in China's disputed zones of core strategic importance. In order to achieve these ambitions, China has been transforming its military, with emphasis on A2/AD capabilities.[1026]

The most fundamental requirement for China's policy towards Taiwan is the need to deter moves in Taiwan toward independence by demonstrating the ability to deter foreign intervention in response to its use of force.[1027] ASBM and other systems are increasingly viewed as a key aspect of an integrated defence system, with other drivers being a strong desire to enforce sovereignty claims in the South China Sea and ensure access to vital resources. China's view that the South China Sea is of vital strategic and economic importance, in terms of establishing itself as a regional military power and countering the US, is consistent with wider fears that the US is trying to contain China through naval dominance, regional bases, and alliances with other regional powers.[1028] China's increasingly assertive approach has fuelled fears that it will impede common use of the sea-lanes and disrupt commerce in the South China Sea.[1029] China claims a segment of the South China Sea extending all the way down to Malaysia and Brunei. Already discussed, the strategically important South China Sea contains some of the world's busiest shipping lanes; it also has valuable fish resources, and some proven oil and gas reserves. The sea also contains hundreds of mostly tiny and uninhabited islands, reefs,

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1024 Editorial, 'The Assassin's Mace: China's Growing Military Might', *The New Atlantis*, no. 6, Summer 2004, pp.107-110.

1025 Krepinvech, *op. cit*., p.22.

1026 Andrew S. Erickson, 'China's Evolving Anti-Access Approach: "Where's the Nearest (U.S.) Carrier?', *China Brief* 10, no. 18, 2010, pp.5-8. For the reasons behind China's military build-up and the possible demise of the US credibility in offering stability in the Western Pacific, see Friedberg, *op. cit.,* pp.218-224. See also, Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2013*, pp.32-33.

1027 Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peoples Republic of China 2010*, pp.47-49.

1028 See Jacques, *When China Rules the World*, pp.374-377.

1029 O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities,* 2008, p.4.

and rocks. China claims almost the entire body of water as its own, and it claims overlap with that of Indonesia, Vietnam, Malaysia, the Philippines, Brunei, and Taiwan.[1030]

The two main island groups in the South China Sea are the Paracel Islands and Spratly Islands, which are disputed territories between Vietnam, China, and Taiwan, with China currently controlling the entire island group. The Spratly Islands consist of around 175 identified islands and reefs, scattered over nearly 160, 000 square miles of sea, and are claimed at present in their entirety by China, Taiwan, and Vietnam. Malaysia and the Philippines have partial claims.[1031] These competing territorial claims are regarded as a potential source of conflict in Asia, and there has been a history of military clashes over sovereign rights in the region; if continued, these clashes present a threat to regional security and the uninterrupted flow of shipping.[1032] In addition to China, Southeast Asian countries are also dramatically building their military.[1033] It would seem an arms race has begun in an attempt to contain China's ambitions in the South China Sea.

Summary

A perspective of the significance of an emerging powerful China, which will increasingly seek to influence its own sphere of interest and be a player on the international stage, is highly relevant. The impact this strategic shift will have upon the rest of the Asia-Pacific region will be seismic, and the defensive strategies of Japan, Taiwan and Australia, in particular, must be seriously considered in view of this potential shift of US influence. The relationships that these countries, *inter alia*, develop with each other, and their attitude towards security and defence doctrine, will shape future international relations. The challenges faced by China and the international community are not insurmountable, but will require concessions from all parties.[1034]

Some observers believe that the US's customary means of projecting power abroad is becoming increasingly obsolete. Andrew Krepinevich argues that: '….the Pentagon is ill-equipped to counter rising powers such as China….Aircraft carriers, navy destroyers, short-

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[1030] See Westad, *op. cit*., pp.421-425.

[1031] For a background analysis on South China Sea issues, see Zou Keyuan, Ocean Development & International Law', *China's U-Shaped Line in the South China Sea Revisited* 43, no. 1, 2012, pp.19-20.

[1032] One school of thought with regard to the PLA's RMA thinking, is the 'Local War' scenario, which focuses on repelling enemy forces infringing on the 'occupied' islands in the South China Sea – see Pillsbury, *op. cit*., p.275.

[1033] Kaplan, 'The South China Sea Is the Future of Conflict', *op. cit.* See also, Abdullah, *The Military Balance: 2013*, pp.245-251.

[1034] Rosemary Foot and Andrew Walter, *China, the United States, and Global Order*, Cambridge: Cambridge University Press, 2011, pp.302-303.

range fighter aircraft and forward bases such as Guam and Okinawa are becoming increasingly vulnerable to technology and tactics being developed by America's rivals'.[1035] This observation emphasises the need to develop a system that is capable of delivering unsupported combat air power at long range and for long periods. The role for conventional deterrence, including that based upon cruise missiles launched from submarines and surface ships, and targeting Chinese military and political installations, will continue to be important. However, the main feature of this conventional deterrence would be rather different from that applied to the Soviet Union. In particular, it will focus upon achieving deterrence with the threat of denial, which is, denying China access to its crucial SLOC, especially for its imports of oil through the South China Sea and its exports of manufactured goods through both the South and the East China Seas. Friedberg believes it is important for the US and its allies, '….to maintain a margin of military advantage sufficient to deter attempts at coercion or aggression'.[1036] As Friedberg points out, '[If] China continues along its present path, growing richer and stronger but continuing under one-party authoritarian rule, it will pose a mounting strategic challenge…this scenario demands urgent and sustained attention from American strategists'.[1037] It will be important for US forces to be able to deny China the capability to exclude the US from these seas; essentially, a counter version of China's A2/AD doctrine.[1038]

While this analysis of China's current foreign policy and military doctrine has not been exhaustive, the author considers it adequate to allow analysis of the use of UCAS. Bearing in mind that the purpose of this thesis seeks to analyse the utility of counter-air UCAS in future warfare, it is important to examine the context in which these systems may be used. The following section analyses the significance of China's A2/AD doctrine, and how this is affecting international relations, and the US's ability to counter China's rise.

China's Anti-Access/Area Denial Doctrine

The concept of air and sea forces conducting the majority of battles in any potential conflict in the Western Pacific is beginning to gain credence. The term 'AirSea' offers a concept designed to maintain a stable military balance in the Western-Pacific, which offsets the PLA's rapidly improving A2/AD capabilities. This concept recognises that this theatre of operations is dominated by naval and air forces and the domains of space and cyberspace

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[1035] Krepinvech, *op. cit.,* p.24.

[1036] Friedberg, *op. cit.,* p.274.

[1037] *ibid.,* p.245.

[1038] Kurth, *op. cit.*, p.589.

– the question is, where do ground forces feature?[1039] In a speech to the National Defense University in 2010, General Schwartz's, the USAF Chief of Staff, addressed the issue of A2/AD doctrine. He was clear that the current 'AirSea' debate should not be focused on any particular threat from China, but rather, it should be viewed in the context of any threat attempting to deny access or hinder US forces from operating in any area of interest.[1040] While this is a rational point of view, the greatest A2/AD threat will come from China, although other states, such as Iran, North Korea and India, may also use this doctrine, basing their philosophy on Chinese writings and military practices.[1041] It is, therefore, prudent to examine China's A2/AD doctrine when analysing the threat to current and future US and other national strategic forces. By doing this, the debate on the utility of UCAS can be better informed.

The US is aligning its strategy and military capabilities, with the aim of mitigating the A2/AD threat. In 2009, Robert Gates, the then US Secretary of Defense, gave an important perspective on the direction US investment in military technology is heading:

> .…when considering the military-modernization programs of countries like China, we should be concerned less with their potential ability to challenge the U.S. symmetrically— fighter to fighter or ship to ship—and more with their ability to disrupt our freedom of movement and narrow our strategic options. Their investments in cyber and anti-satellite warfare, anti-air and anti-ship weaponry, and ballistic missiles could threaten America's primary way to project power and help allies in the Pacific—in particular our forward air bases and carrier strike groups. This would degrade the effectiveness of short-range fighters and put more of a premium on being able to strike from over the horizon—whatever form that capability might take.[1042]

Researchers have postulated a potential Chinese strategy for seeking to drive US forces out of the Asia-Pacific region, one similar to the Imperial Japanese strategy of 1941-1942.[1043] Following the US, British and Dutch embargo of the supply of oil to Japan and the freezing of assets in 1941, Japan was determined to break these restrictions by force, if necessary. A political solution was not forthcoming. Seventy-five percent of Japan's foreign trade, and 90% of her oil supplies were cut off. Despite efforts from the US, Britain and Holland to negotiate with Japan over its position in China and its partnership with

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[1039] For an overview of the Air-Sea Battle concept in relation to A2/AD threats, see Abdullah, *The Military Balance: 2013*, pp.29-31.

[1040] General Norty Schwatz USAF, CSAF, 'The Air-Sea Battle Concept', *National Defense University Distinguished Lecture Program*, 15 December 2010, http://www.af.mil/shared/media/document/AFD-101216-016.pdf, (accessed 6 January 2010).

[1041] Harry Kazianis, 'Anti-Access Goes Global', *The Diplomat*, 2 December 2011, http://the-diplomat.com/flashpoints-blog/2011/12/02/anti-access-goes-global/, (accessed 3 February 2012).

[1042] US Secretary of Defense Robert M. Gates, *U.S. Department of Defense*, 16 September 2009, http://www.defense.gov/speeches/speech.aspx?speechid=1379, (accessed 5 August 2010).

[1043] Richard Halloran, 'Airsea Battle', *Air Force Magazine* 93, no. 8, 2010, p.47.

Germany, Japan was persuaded by Germany to take the offensive.[1044] Japan's stance over China was pivotal; the US would allow oil shipments from the Dutch East Indies, but only if Japan withdraw from China. Japan was not prepared to do this.[1045] According to the US Army official history of World War II: 'In the view of the leaders of Japan, there was no honourable choice but war. The US and Great Britain, they were convinced, were bent on destroying Japan or reducing it to a minor power'.[1046] Japan had informed the Germans as early as the beginning of 1941 that plans were being made for War against the US.[1047]

The Japanese mounted a surprise attack on Pearl Harbour on December 7, 1941, intending to destroy the US Pacific Fleet. Concurrently, the Japanese Army invaded the Philippines and what is now Malaysia, before moving on to Singapore. Strategically critical islands in the South Pacific were also occupied, with India and Australia threatened.[1048] Japan's intent was to present the Western powers with a *fait accompli* from an unassailable position and sue for peace. Their strategy was flawed, not least, because Japan was unable to maintain control of the air in its sphere of operations. According to Richard Overy, in *The Air War: 1939 – 1945,* because of the importance of the strategic use of aircraft by all sides in the Pacific/China theatre of operations, gaining and maintaining air supremacy was essential to the success of the Pacific campaign.[1049] Overy writes:

> The Japanese inability to maintain the supremacy temporarily wrested from the Allies in early 1942, and the Allied determination to build up massive and diversified air power before resources for invasion could be diverted from the European theatre, led to the final defeat of Japan through blockade and destruction by air.[1050]

Although Japan's strategy was seriously flawed, it taught that no scenario can be totally disregarded. The future possibility of conflict in the Western Pacific does feature in some analysts' assessments. Henry Kissinger, for example, believes there are comparisons between British-German rivalry in the twentieth-century, and between China and the US in the twenty-first century.[1051] In relation to China and the US, Kissinger observes:

[1044] See A. J. P. Taylor, *The Second World War and Its Aftermath*, London: The Folio Society, 1998, pp.100-101.

[1045] Marc Trachtenberg, 'Preventive War and U.S. Foreign Policy', *Security Studies* 16, no. 1, 2007, p.23.

[1046] Morton, *op. cit*., p.127.

[1047] *ibid.,* p.64.

[1048] The historian A. J. P Taylor believed that the attack on Pearl Harbour should not have come as a surprise. The US had broken the Japanese codes, and actually sent out a general warning that war was imminent on 27 November - see A. J. P. Taylor, *op. cit*., p.103.

[1049] Overy, *The Air War: 1939 - 1945*, p.85.

[1050] *ibid.*

[1051] Kissinger, *op. cit.,* p.514.

> An international system is relatively stable if the level of reassurance required by its members is achieved by diplomacy. When diplomacy no longer functions, relationships become increasingly concentrated on military strategy – first in the forms of arms races, then as a manoeuvring for strategic advantage…, and, finally, in war itself.[1052]

The doctrine developed by the US DoD following the Cold War was based on the convention that it would be able to deploy and operate its forces from bases comparatively unimpeded by adversary threats.[1053] These assumptions extended to the operations of tactical fighter aircraft, CSG, AAR and ISTAR assets and networks, and all support personnel and logistics. The 1991 Gulf War reinforced these assumptions and contributed to the US DoD's development of a new doctrine based on structuring US forces primarily for conducting two nearly simultaneous regional conflicts, for example, in Iraq/Iran and Korea.[1054] In 2012, the US announced it would be adopting a new strategy, which, '… commits the Pentagon to being able to fight a single large-scale war while retaining enough forces to deter or impose unacceptable costs on an opportunistic aggressor in a second region'.[1055] Long-range strike was viewed as an initial requirement needed to rapidly halt adversary forces; subsequently, short-range tactical aircraft flying from nearby bases in relatively permissive operating environments could carry out the majority of strike missions. Mark Gunzinger, from CSBA, believes this investment in short-range combat aircraft has led to a paucity of investment in long-range strike programmes.[1056] Range and persistence are now becoming the dominating requirement against adversaries with an A2/AD strategy.

China is developing a capability that could alter the strategic balance in the Asia-Pacific region and beyond. Research is on-going into development of a range of systems which will allow China's A2/AD strategy to be realised.[1057] China's 'Assassin's Mace' doctrine, aligned with its very real desire to bring back Taiwan within its sphere of influence, is having a dramatic effect on the US's ability to influence policy in the Asia-Pacific region, specifically, in the region that China regards as the First Island Chain. The phrase *'*Assassin's Mace*'* is the English translation of '*Shasho Jiang'*, a term of ancient Chinese strategy. There are, however, a number of different meanings. The term is used to designate a wide array of technologies that might afford an inferior military an advantage in

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1052 *ibid*., p.515.

1053 See Gunzinger, *Sustaining America's Strategic Advantage In Long-Range Strike*, p.x.

1054 *ibid.,* p.x.

1055 Craig Whitelock and Greg Jaffe, 'Obama Announces New, Leaner Military Approach', *The Washington Post*, 5 January 2012, http://www.washingtonpost.com/world/national-security/obama-announces-new-military-approach/2012/01/05/gIQAFWcmcP_story_1.html, (accessed 19 Octber 2012).

1056 See Gunzinger, *op. cit*., p.x.

1057 Mark Stokes, *op. cit.*, p.i. See also, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2013*, pp.30-39.

a conflict with a superior military power.[1058] *Shasho Jiang* is not seen as a panacea, but, if the correct strategy is used, aligned with the correct timing and conditions, then a superior adversary can be defeated.[1059]

China's A2/AD doctrine has been evolving over a number of decades, and increasingly, technical and operationally focused discussions are found in a range of Chinese sources, suggesting that China may be close to employing an ASBM - a weapon that no other country currently possesses.[1060] An example of China's determination to achieve this is the recent development of the *Dong-Feng* DF-21D ASBM (NATO designation: CSS-5), modified to sink aircraft carriers.[1061] This ASBM is intended to provide the PLA the capability to attack ships, including aircraft carriers, in the Western Pacific Ocean.[1062] It can be argued that this ASBM is a game changer and is fundamental to the strategic shift in current US thinking. Its imminent deployment could restrict US fleet operations to outside of the 'First Island Chain', drastically limiting US capabilities and influence. This shift in the balance of power in the Western Pacific is fundamental to the type of system that will be required to counter China's forces.[1063] Figure 4 below details the 'two island chains', and a number of potential weapon systems.

[1058] For an analysis of the meanings and significance of 'Assassin's Mace' doctrine, see Jason E. Bruzdzinski, 'Demystifying Shashoujian: "China's Assassin's Mace" Concept', in *Civil-Military Change in China Elites, Institutes, and Ideas after the 16th Party Congress*, Andrew Scobell and Larry Wortzel (eds), Darby, PA: Diane Publishing Co, 2004, pp.309-354.

[1059] *ibid.,* p.348.

[1060] For an historical perspective on China's A2/AD doctrine and ways of better recognising these types of paradigm shifts in capabilities, see Dr Thomas G. Mahken, 'China's Anti-Access Strategy in Historical and Theoretical Perspective', *Journal of Strategic Studies* 34, no. 3, 2011, pp.299-323.

[1061] Michael Evans, 'Pentagon Strengthens Defences to Protect Europe', *The Times*, 18 October 2010, p.31. China refers to the DF series of ballistic missile as the *Dongfeng*. NATO's designation for the DF-21D is CSS-5 - see National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat,* Dayton, OH, 2010, p.16 - see also, Daly, *op. cit.,* pp.25-26.

[1062] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010*, p.2.

[1063] For a discussion on China's ASBM development and its implications for the US and its allies, see Michael Chase, Andrew Erickson, and Christopher Yeaw, 'Chinese Theater and Strategic Missile Force Modernization and Its Implications for the United States', *The Journal of Strategic Studies* 32, no. 1, 2009, pp.67-114.

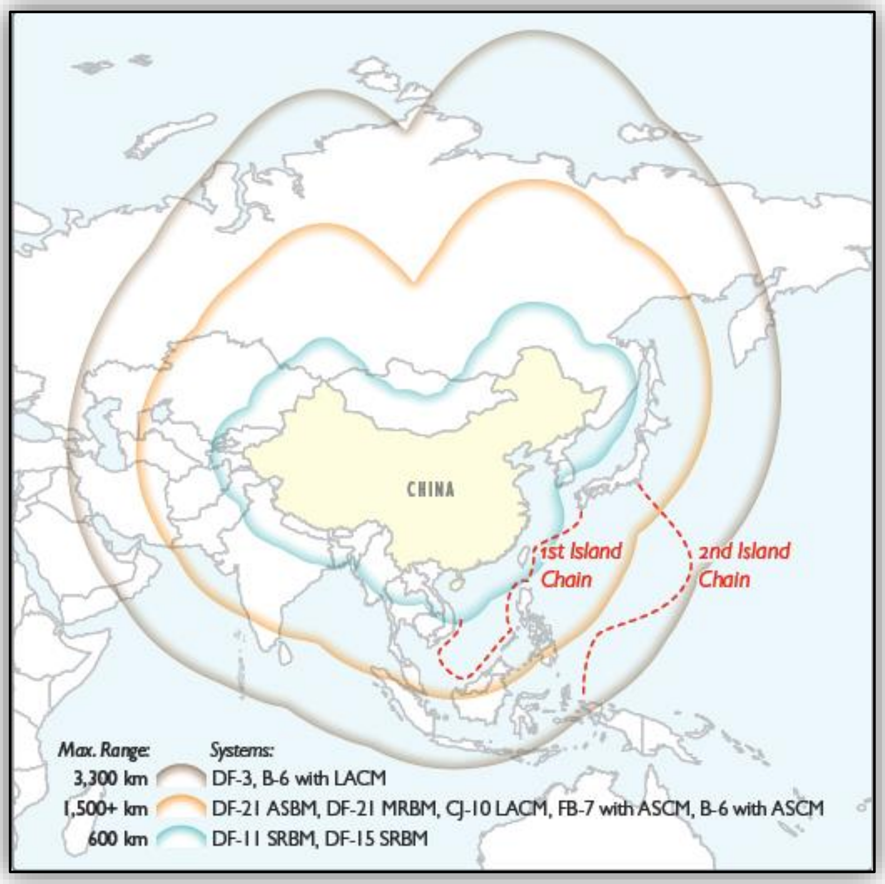

Figure 4: The First and Second Island Chains, and ranges of weapon systems.[1064]

China wants to achieve the ability, or at least the appearance of such an ability, to prevent a US CSG from intervening in the event of a future Taiwan Strait crisis. China has designed the DF-21D to be an A2/AD weapon with the specific intent of sinking a US aircraft carrier; it appears that the DF-21D has already been tested.[1065] Chinese writings indicate a near term requirement to keep US CSG at a distance of at least 1100 nm from China's eastern coastline.[1066] The deployment of an effective ASBM, such as the DF-21D, and part of a matrix of systems, could achieve this objective, profoundly affecting US deterrence, military operations and the balance of power in the Western Pacific.

[1064] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the Peolpe's Republic of China 2012,* Washington, DC: 2012, http://www.defense.gov/pubs/pdfs/2012_CMPR_Final.pdf, (accessed 29 August 2012), p.42.

[1065] Andrew S. Erickson, 'Chinese ASBM Development: Knowns and Unknowns', *China Brief* 9, no. 13, 2010, pp.5-6.

[1066] See Mark Stokes, o*p. cit*., p.1. Michael Pillsbury was one of the first to establish from Chinese writings the interest in vulnerabilities of US carriers – see Pillsbury, *op. cit.,* pp.83-85.

The ASBM would be just one of the many new platforms and weapons systems that China has been developing since the 1996 Taiwan Strait Crisis. However, an ASBM such as the DF-21D has the potential, well beyond the submarines and Anti-Surface Cruise Missiles (ASCM), which China has been adding to its cache of weapons, to create a strategic shock among regional allies of the US. Although in development since 1996, it was not until 2007, when Chinese rocket artillery and engineering papers were published suggesting that the capability was advancing, that the threat was taken seriously. It was at this point that the US started to take notice, and action.[1067]

As well as advances in ASBM technology, China is on the verge of achieving a number of game-changing developments, including the ability to launch multiple cruise missile attacks, robust indigenous satellite navigation, high quality real-time satellite imagery, target-locating data, and anti-satellite (ASAT) and other space-related weapons.[1068] Should China wish to prevent access to a contested maritime area in the event of conflict, such accomplishments would significantly advance China's A2/AD capabilities by allowing it to threaten the whole gamut of surface- and air-based assets.

The US government is acutely aware of the threat from the DF-21D. The *2010 Annual Report to Congress* does not mince its words:

> China is developing an anti-ship ballistic missile…The missile has a range in excess of 1,500 [km], is armed with a maneuverable warhead, and when integrated with appropriate command and control systems, is intended to provide the PLA with the capability to attack ships, including aircraft carriers, in the western Pacific Ocean.[1069]

The report also points out that the PLAN is improving its over-the-horizon (OTH) targeting capabilities with new radar systems to support long-range precision strikes, including those by ASBM. The report emphasises China's intent over Taiwan:

> China's long-term, comprehensive transformation of its military forces is improving its capacity for force projection and anti-access/area-denial. Consistent with a near-term focus on preparing for Taiwan Strait contingencies, China continues to deploy many of its most advanced systems to the military regions (MRs) opposite Taiwan.[1070]

An effective ASBM and persistent maritime surveillance capability would form part of the matrix of capabilities that could prevent the US challenging Chinese use of force against Taiwan, ultimately undermining the principles of the Taiwan TRA. Aligned with the *2010*

[1067] Mark Stokes, *op. cit.*, p.36.

[1068] Eric Hagt and Matthew Durnin, 'Space, China's Tactical Frontier', *Journal of Strategic Studies* 34, no. 5, 2011, pp.748-749.

[1069] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010*, p.1.

[1070] *ibid.*

Report to Congress, other US governmental departments believe China's extensive campaign to modernise its military forces is moving forward at an alarming rate. The National Air and Space Intelligence Center's report on Chinese military-technological development, observes:

> China has the most active and diverse ballistic missile development program in the world. It is developing and testing offensive missiles, forming additional missile units, qualitatively upgrading certain missile systems, and developing methods to counter ballistic missile defenses. China's ballistic missile force is expanding in both size and types of missiles. New theater missiles continue to be deployed in the vicinity of Taiwan…[1071]

In recent years, this build-up has generated some significant new capabilities, all of which serve China's broader strategic and political strategies in the Asian-Pacific region. The *2010 Annual Report to Congress* warns, 'China is aggressively pursuing the military capabilities necessary to wage and win a short-duration, high-intensity conflict with Taiwan—and with the US, should it ever intervene'.[1072] A proposed follow-on variant to the DF-21D would extend an ASBM's range to 1500 nm**.** Subsequent technological advances could extend a conventional precision strike capability out to 4500 nm. Figure 6 details a possible layered ASBM strike architecture. The extended range of an ASBM would not necessarily mean its CEP is worse – the limiting factor would remain the same, finding and tracking a target.

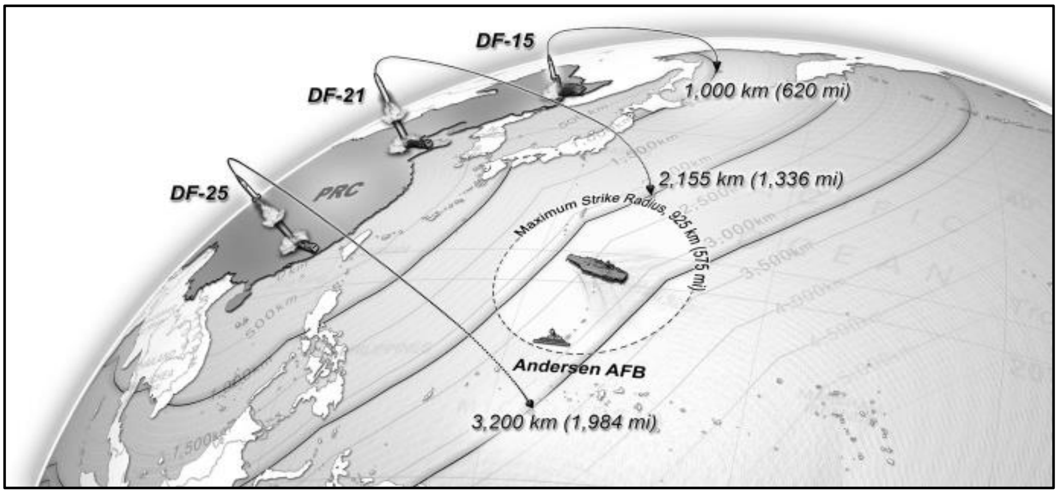

Figure 5: Possible layered ASBM strike architecture, with 1000, 2000 and 3000 km range ASBM strike assets.[1073]

[1071] National Air and Space Intelligence Center, *op. cit.,* p.3.

[1072] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010*, p.1.

[1073] Mark Stokes, *op. cit.,* p.2.

China's military strategists have also been evaluating the feasibility of a global conventional strike capability as an incremental follow-on to the successful deployment of an initial ASBM. China plans to field a fully functional Precision Global Strike capability by 2025.[1074] In a future Taiwan scenario involving US military intervention, China could reserve the option to conduct conventional precision strikes against unhardened facilities that support US operations, including facilities in Hawaii, the US, Australia, and elsewhere.[1075] These conventional systems would also be utilised with the intention of enforcing China's regional sovereignty claims and ensuring the SLOC remain secure. Ultimately, successful deployment of conventional ballistic missiles and other precision strike systems would offer China a flexible deterrent.[1076] A study from the RAND Corporation explores the outcomes of a range of scenarios of a US and Taiwan alliance, against a determined effort by China to take Taiwan by force. The conclusions are emphatic: China will likely have the capabilities to achieve its aims, if the appropriate counters are not instigated.[1077] China's doctrinal strategy, aligned with the new panoply of weapons, could achieve the desired strategic and operational effect, giving China the edge in a contest of wills, or indeed, in an actual kinetic confrontation. The balance of power in the Pacific would radically change.

Counters to China's Anti-Access/Area-Denial Doctrine

In January 2009, Secretary of Defence Robert Gates stated: '…the Department of Defense is making good progress toward developing a number of programs to counter Chinese technological advances that could put our carriers at risk.'[1078] US military officials have stressed that the development of new electronic jammers, a long-range nuclear capable bomber, modernised radars for the F-15, and significantly, new sea-borne UCAS will help mitigate this threat.[1079] It is not certain, however, if these programmes will be successful. According to Stokes, the US may need to reassess its capabilities, including different types of ships and submarines. The hardening of US military facilities throughout the Pacific region, including Kadena Airbase on Okinawa and facilities on Guam and Hawaii, will also need to be seriously considered.[1080] Most significantly, long-range UCAS may offer a

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1074 *ibid.,* p.2.

1075 *ibid*., pp.36-37.

1076 See *ibid.*, p.i.

1077 For a summary of the potential scenarios, and the recommendations to counter these, see David A. Shlapak and others, *A Question of Balance: Political Context and Military Aspects of China-Taiwan Dispute*, Santa Monica, CA: RAND Corporation, 2009, pp.123-143.

1078 Transcript of the Committee on Armed Services: United States Senate, 'The Challenges Facing the Department of Defense', 27 January 2009, http://www.gpo.gov/fdsys/pkg/CHRG-111shrg53123/html/CHRG-111shrg53123.htm, (accessed 21 August 2012).

1079 Daniel Dombey, 'China's New Doctrine', *Financial Times*, 10 January 2011, p.4.

1080 Mark Stokes, *op. cit*., p.36.

solution in providing the capability to conduct the full gamut of OCA and strike missions, if access is denied to CSG and close land-based assets. Mark Gunzinger recommends that the US, 'Develop an air-refuelable naval UCAS with at least a 1500 nm combat radius and the all-aspect, broadband low-observable characteristics required to survive in the face of advanced air defense networks…'.[1081] Krepinevich also argues that: 'To avoid operational irrelevance, carriers should reduce their reliance on short-range manned aircraft in favor of much longer-range unmanned aircraft...'.[1082] Significantly, these proposed UCAS will not be able to conduct the full gamut of counter-air roles.

China's Anti-Ship Ballistic Missile Development

An ASBM system, if developed and deployed successfully, would be the world's first weapons system capable of targeting a moving CSG, at sufficient range to severely curtail any current aircraft carrier's effectiveness. This could pose a new type of threat to the USN and other navies; the US has not had decades to tackle this new challenge. Even if capable of doing so, if the US was to target these ASBM and supporting C4ISTAR infrastructure, with strikes in mainland China, the reaction would be incalculable.[1083]

China has prioritised ballistic missile (BM) development for decades, enjoys an impressive science and technology base, and will likely continue to dedicate considerable resources to ASBM development. The DF-21D challenges the technological superiority the US has maintained in carrier-borne capabilities for decades; this technological superiority is the foundation of the US's military dominance in the Western Pacific.[1084] The DF-21D can be launched in the general direction of a US Navy CSG , and while in flight, adjust course to directly target an aircraft carrier, or other selected sea-borne targets. This ability to alter course during flight is a significant technological evolution. No current Anti-Ballistic Missile (ABM) defence system has an acceptable probability of intercepting a BM that can significantly alter its course during flight. This capability gives the DF-21D its advantage against existing US ABM defence systems.[1085] ABM are launched near the intended flight-path of a BM; when the ABM is within a predetermined distance from the BM, the terminal guidance and detection system of the ABM should be able to detect and intercept it. However, because the DF-21D alters course at high altitude and detects its target after

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[1081] Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike,* pp.xiii-xiv.

[1082] Krepinvech, *op. cit.,* p.30.

[1083] Erickson, 'China's Evolving Anti-Access Approach', p.6.

[1084] Friedberg, *op. cit.,* pp.221-222.

[1085] Raymond Pritchett, 'Chinese Fireworks on the 4th of July', *The Intersection of Maritime Strategy and Strategic Communications*, 1 July 2010, http://www.informationdissemination.net/2010/07/chinese-fireworks-on-4th-of-july.html, (accessed 16 September 2010).

launch, the calculations sent to an ABM defence system would be incorrect. It will be extremely difficult for any current ABM defence system to detect and defeat the DF-21D ASBM.[1086]

The diagram below appeared in a 2006 article from the PLA's Second Artillery College. It describes in very simple terms the guidance and trajectory laws used by an ASBM. There is nothing particularly revelatory with this concept, however, achieving effectiveness is another question all together.

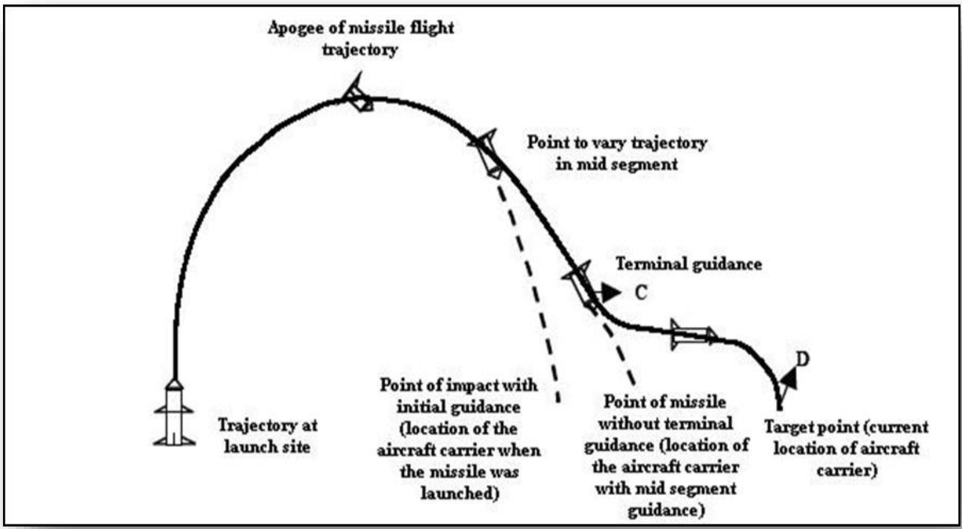

Figure 6: Missile flight trajectory with terminal guidance showing an ASBM's use of midcourse and terminal guidance to strike an aircraft carrier.[1087]

Indicators of successful development of the DF-21D include the recent launch of five *Yaogan* satellites – these would offer significantly better coverage of critical areas along China's maritime area of interest. Another indication is a news release from the China Aerospace Science & Industry Corporation (CASIC) citing Wang Genbin, Deputy Director of its 4th Department, stating: 'the DF-21D can hit slow-moving targets with a CEP of dozens of meters.'[1088] It is likely that when the successful development of the DF-21D is complete, China would reveal a test, attempting to influence opinion in the US, Taiwan,

[1086] *Ibid.*

[1087] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010*, p.36.

[1088] Pritchett, *op. cit.* Circular Error Probable (CEP) is the measure, where EP is the radius of a circle, centred on the mean or intended fuse point, in which 50% of the weapons are expected to arrive or in which a single weapon has a 0.5 probability of arriving - see Capt. Peter Puhek USAF, *A Sensitivity Analysis of Circular Error Probale Approximation Techniques',* USAF Air University - Air Force Institute of Technology, 1992, pp.3.1-3.5.

Japan, and elsewhere in the Asia-Pacific.[1089] In an interview to a Japanese newspaper, Admiral Robert Willard, commander of US Pacific Command stated, 'To our knowledge, [the DF-21D] has undergone repeated tests, and it is probably very close to being operational'.[1090] The *Washington Times* also reports that China conducted a long-range missile test on 25 September 2010.[1091]

As with many military doctrinal and capability developments, the deterrent effect of merely possessing the means of denying access could achieve the desired strategic aims. Some Chinese writers believe that even the significant likelihood of a capability, may have a substantial deterrent effect. The ASBM is envisaged primarily as a deterrent weapon by Chinese analysts; to many this makes it inherently defensive in nature. An editorial, in *Global Times,* gives an insight into the philosophies of the Chinese media. The editorial advocated China's need for powerful ASBM and other carrier-destroying measures. Significantly, it emphasised the requirement for deterrence, and the need to publicise the capability:

> China has never pursued a policy of confrontation with other world powers, including the US. However, it does need a strategic deterrence. In a bid to protect its own strategic interests, China should not only build its anti-ship missile capacity, but also possess a range of other carrier-destroying measures as well....Since US aircraft carrier battle groups in the Pacific constitute deterrence against China's strategic interests, China has to possess the capacity to counterbalance.…Such capacity could inhibit US thoughts of keeping China in check through aircraft carriers, and therefore greatly reduce the possibility of confrontation between the People's Liberation Army and US military forces in the Western Pacific.…An external anxiety over China's development of its military is somewhat understandable. The greater strategic deterrence China possesses, the more cautious it should be in using force. China should carefully explore how to present its deterrence. This is a new subject for China.…To end "speculation" by Western intelligence agencies…China ought to convince the international community of its reliable carrier-killing capacity as soon as possible…[1092]

The sequence of events required for any BM to successfully engage and destroy or disable a target is known as the 'Kill Chain'. All parts of this are required to work; if any one part should fail, the objective will not be achieved. For a moving target, such as a ship, the task is significantly more difficult. The essential core of this capability is a missile-borne sensing and data processing system, supported by an initial cueing from a surveillance network,

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[1089] Erickson, 'China's Evolving Anti-Access Approach', p.6.

[1090] Yoichi Kato, 'China's Anti-Ship Missile Is Nearly Operational', *The Ashai Shimbun*, 26 August 2010, http://www.asahi.com/english/TKY201008250379.html, (accessed 21 October 2010).

[1091] Bill Gertz, 'Inside the Ring: Chinese Missile Test', *The Washington Times*, 6 October 2010, http://www.washingtontimes.com/news/2010/oct/6/inside-the-ring-488593726/, (accessed 15 Novemebr 2010).

[1092] Editorial, 'China Needs Powerful "Carrier Killers"', *Global Times*, 6 Septemebr 2010, http://opinion.globaltimes.cn/editorial/2010-09/570320.html, (accessed 10 October 2010).

which would include, *inter alia*, UAS, OTH radar and satellites.[1093] According to the *2010 Annual Report to Congress*, the PLAN is improving its OTH targeting capability with Sky Wave and Surface Wave OTH radars. OTH radars can be used in conjunction with imagery satellites to assist in detecting targets at great distances from China's shores to support long-range precision strikes, including by ASBM.[1094] As well as OTH radars, China has also been working on a sophisticated network of ground- and space-based sensors, including electronic signals detection equipment, which can assist ASBM detection and targeting. Chinese UCAS survivable in highly contested airspace could also be used to assist third-party-targeting systems. It is also likely decoy UAS would be used as decoys; the aim would be to exhaust AAM and SAM stocks. These decoys could also use EA systems.[1095] Active radar is the most likely ASBM sensor, for the 'track' part of the kill chain. The largest reflection would normally be the largest ship, usually an aircraft carrier. However, as with any radar-based sensor, deception techniques could be used to fool the ASBM into believing it was targeting a carrier.[1096] EA techniques are extensively used to counter AAM, SAM, and all forms of radar. However, counters to EA techniques are always being developed.[1097]

Chinese PLA writings emphasise coordination and precision as being vital for deterring and blocking enemy CSG. Locating sea targets is also stressed, with real-time target intelligence being critical, with the use of military reconnaissance satellites, domestic and foreign remote sensing satellites, and established satellite reconnaissance target image information processing systems, being considered paramount.[1098] Developments in access to foreign satellite navigation-positioning systems, such as the Russian *Glosnast* and US GPS, increase the accuracy of Chinese BM and other weapon systems. The development of a viable independent system, *Beidou*, could allow access to a reliable source of navigation accuracy during a conflict scenario. China's current four-satellite *Beidou*-1 constellation, deployed in 2007, is limited to supporting operations on China's near maritime border and is accurate to within approximately 20 m – not enough for precision

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[1093] Ian M. Easton, and L.C. Russell Hsiao. *The Chinese People's Liberation Army's Unmanned Aerial Vehicle Project: Organizational Capacities and Operational Capabilities* Arlington, VA: Project 2049 Institute, 2013. http://project2049.net/documents/uav_easton_hsiao.pdf, (accessed 13 March 2013), pp.13-14.

[1094] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010,* p.2.

[1095] See Easton and Hsiao, *op. cit.,* p.14.

[1096] Pritchett, *op. cit.*

[1097] The PLA is at the forefront of EW doctrine and implementation – see Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2013,* p.37.

[1098] Erickson, 'Chinese ASBM Development: Knowns and Unknowns', pp.6-7.

strike targeting.[1099] To reliably support wider operations, China is deploying a 35-satellite (5 geostationary, 30 medium earth orbit) constellation—*Beidou*-2/Compass—which would provide much-improved accuracy, with global navigation coverage by 2015-20.[1100]

US military commanders and politicians are increasingly giving their candid views on the subject of ASBM. During a speech to North Carolina ROTC students on 29 September 2010, Secretary of Defence Robert Gates emphasised the need to factor ASBM development into future carrier operations:

> If the Chinese or somebody else has a highly accurate anti-ship cruise or ballistic missile that can take out a carrier at hundreds of miles of ranges and therefore in Asia puts us back behind the second island chain, how then do you use carriers differently in the future than we've used them in the past?…I'm trying to get people to think about how do we use [carriers] in a world environment where other countries will have the capability, between their missile capabilities and their satellite capabilities, to knock out a carrier if you get to a certain point… within range.[1101]

Gate's speech is clear. How seriously the US takes the development of the DF-21D is evident in the US Navy's fundamental revolution in its development of ABM defences. The USN's defence against this type of threat has continued to rely on the strategy of defence in depth. Guns were replaced in the late fifties by the first generation of guided missiles in ships and aircraft. By the late sixties, it was recognised that reaction time, firepower, and operational availability in all environments did not match the threat. As a result, an operational requirement for an Advanced Surface Missile System (ASMS) was promulgated and a comprehensive engineering development programme was initiated to meet that requirement. ASMS was renamed AEGIS (after the mythological shield of Zeus) in December 1969.[1102] The concern defence analysts have regarding the future of the aircraft carrier in the 21st century is due, in large part, to the game-changing nature of the development of the DF-21D. The acceleration of plans regarding the capabilities of the AEGIS weapon system is largely owing to recognition that current systems are not capable of addressing this threat. The DF-21D and US AEGIS ABM defence system represents the first major offensive/defensive military capability arms race of the 21st century.[1103] Gates

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[1099] *ibid.,* p.7.

[1100] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2010,* p.36.

[1101] U.S. Department of Defense, 'News Transcripts: Remarks by Secretary Gates to North Carolina ROTC Students', 29 September 2010, http://www.defense.gov/transcripts/transcript.aspx?transcriptid=4692, (accessed 23 October 2010).

[1102] For an overview of the AEGIS, see Fuller, *op. cit.,* pp.182-189.

[1103] Pritchett, *op. cit.*

authorised increased investment in weapon systems to counter the growing potential threat posed by China's advanced aircraft and missiles.[1104]

Although deterrence would seem to be a clear purpose of any ASBM development, there are a number of questions regarding its operating doctrine: how would an ASBM be used to deter? How would the US respond to this? How would the US know it was a warning shot and not just a miss? There is a well-founded fear that China's military transformation, aligned with a perceived lack of coherent doctrine, may lead to mismanagement of any crisis scenario. Ultimately, how robust is China's ability to risk-manage, without threatening an escalation in tension, with unpredictable results?[1105]

Summary

China is intent on fielding a capability that could weaken the capacity of the US to assist Taiwan in a conflict scenario. While open source reporting indicates that ASBM production has begun and has indeed been tested, it cannot be confirmed when an ASBM will be operationally available. Western intelligence agencies should, however, be able to monitor Chinese developments, including any ASBM testing, pending any formal declaration by China. China's deployment of an ASBM capability could change the strategic balance in the Asia-Pacific region. The PRC's goal is to create the conditions for Taiwan's unification on satisfactory terms, in which regard the US is viewed as the principle remaining hurdle to unification. As well as a real Chinese capability to prevent the US's capacity to intervene in a future crisis, the perception would be created within Taiwan of US weakness.[1106] It is unlikely that China would use ASBM in isolation. ASBM would be backed by a maritime surveillance network, theatre BM and extended range cruise missiles, designed to be launched from both conventional and nuclear-powered attack submarines. These could operate in conjunction with submarines, conventional naval aviation, and EA assets. Follow-on ASBM variants are likely to strain the ability of US ABM defences, unless fundamental initiatives are taken to develop an anti-ASBM system, capable of negating this type of threat. Forced to operate out of range of these ASBM, the effectiveness of carrier-

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[1104] Evans, 'US 'Failed to Spot China's Rapid Advance in Missiles and Jets'', *op. cit.* A US Congressional Research Service analysis, describes the potential counters to China's ASBM, in particular, what is required to break the ASBM's 'Kill Chain' – see Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities - Background and Issues for Congress,* Washington, DC: Congressional Research Service, April 2013, http://www.fas.org/sgp/crs/row/RL33153.pdf, (accessed 21 May 2013). pp.63-64.

[1105] Erickson, 'China's Evolving Anti-Access Approach', pp.5-8.

[1106] Mark Stokes, *op. cit*., p.35.

based assets, such as the F/A-18E/F, would be even more limited than they already are, when forced to fight at greater ranges than in the past.[1107]

China's A2/AD doctrine gives China a strategic advantage, and it appears increasingly confident of its ability to deny US CSG the ability to intervene in a Taiwan scenario. Overall US qualitative and numerical superiority is of limited relevance. First, the platforms most likely to be employed by the US are those that are based within immediate striking distance from Chinese weapon systems at the outbreak of conflict; here China inherently enjoys the advantage. Second, aircraft sent to the Asia-Pacific region require bases from which to operate; US regional options are limited geographically and politically, and are vulnerable to Chinese attack. Indeed, China need not keep pace with Western technologically to have a huge influence.[1108] If China's intent on fielding a system that directly threatens US carriers is not neutralised, the US military alliances and reassurances which have helped maintain peace in the Western Pacific since World War II would be severely weakened; an arms race would inevitably ensue, if it has not already. It is probable that China does not plan to attack US forces, but to deter them. China states that it wants to protect its fundamental territorial interests and to ensure a stable environment for economic development. If ASBM are ultimately developed, China would hope to prevent US projection of military power in circumstances that are hostile to China's security interests. Yet ASBM development for this purpose is complex. China has demonstrated an ASBM intent, if not capability, with substantial tensions certainly now developing. Unless China is willing to open a dialogue regarding its intentions, it will be essential for governments in Taiwan, Japan, the US, and other affected states, to force multi-lateral debate, failing which, to respond with appropriate measures. Krepinevich perhaps best sums up the US dilemma:

> The implications of these efforts are clear. East Asian waters are slowly but surely becoming another potential no-go zone for U.S. ships, particularly for aircraft carriers, which carry short-range strike aircraft that require them to operate well within the reach of the PLA'S A2/AD systems if they want [to] remain operationally relevant. The large air bases in the region that host the U.S. Air Force's short-range strike aircraft and support aircraft are similarly under increased threat. All thus risk becoming wasting assets.[1109]

As Eric Gons points out in his PhD thesis, 'If forced to operate outside 1,500 km, naval aviation will not be able to contribute heavily to the counter-air effort. And if using USAF

[1107] Bill Sweetman, 'Antiship Missiles Engage Diverse Targets', *Aviation Week: Defense Technology International*, 6 May 2009, http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=dti&id=news/ANTI050609.xml, (accessed 29 September 2010).

[1108] Erickson, 'China's Evolving Anti-Access Approach', pp.5-7.

[1109] Krepinvech, *op. cit.,* p.23.

tankers, USN aircraft will be displacing USAF aircraft tailored more specifically to the air superiority mission'.[1110] The strategic balance is changing; there is a requirement for systems that counter this emerging threat. There is also a requirement for extended range and endurance air platforms; UCAS could form part of the required matrix for gaining and maintaining control of the air in the Asia-pacific region, thereby fulfilling the air domain's part of the 'AirSea' contract, and acting as a deterrent. The US's aircraft procurement strategy acknowledges the significance of anti-access threats, which, '…could impede the deployment of U.S. forces to a conflict and blunt the operations of those forces that do deploy forward'.[1111] The US Navy, in particular, with its Next Generation Air Dominance (NGAD) aircraft study, is cognisant of the issues; it is looking at replacing the F/A-18E/F and F-35 with, '…a new manned or unmanned platform or a combination of both'.[1112]

Aircraft carriers are widely seen as exemplars of technological prowess and military dominance. The US, in particular, has supremacy in the number of carriers and support ships its navy possesses, with 11 CSG currently available.[1113] These CSG form the foundation for US rapid response and power projection and, *inter alia*, deterrence. What happens if these CSG are forced to stay outside of range of adversary attack systems? What if countries, such as China, establish doctrine that aims to make it so costly to an adversary to commit forces within its sphere of influence that their mighty military systems become so ineffective?

When viewed in a conflict scenario in which an adversary has an A2/AD strategy, some of the counter-air maxims generally assumed may be invalidated, such as the capability to operate from close bases and aircraft carriers.[1114] In the case of China, it is building up its forces and establishing doctrine and procedures to enforce such a policy. Chinese threats to CSG include ASBM, submarines equipped with torpedoes and extremely capable ASCM, plus aircraft carrying ASCM. China can also threaten air bases with short-range ballistic missiles, intermediate-range ballistic missiles, and land- and air-launched cruise missiles. Ultimately, it may be feasible that large, sophisticated Chinese air, naval and missile forces can mass against a relatively small number of US CSG and air bases in the

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[1110] Gons, *op. cit.,* p.75.

[1111] US Department of Defense, 'Aircraft Procurement Plan: Fiscal Years (FY) 2012-2041', Washington, DC, 2011, p.8.

[1112] *ibid.,* p.16.

[1113] United States Navy, 'United States Navy Fact File: Aircraft Carriers - CVN', *Navy.mil*, 2011, http://www.navy.mil/navydata/fact_display.asp?cid=4200&tid=200&ct=4, (accessed 23 June 2011).

[1114] A2/AD strategies which force operations from greater distances than those currently planned, mean systems with greater range and endurance are required - see Gunzinger and Dougherty, *op. cit.,* p.87.

Western Pacific. In this context, the efficacy of UCAS gaining control of the air demands thorough scrutiny.

Iran

While the significance of the Western Pacific will continue to test the foreign and military policies of the US, its allies and others, the importance of the Middle East in international affairs is also obvious. Two factors drive tensions in the region - oil, and separately, Israel, and its relationship with other Middle East states. Within this Middle East context, Iran poses the greatest potential threat to Western interests, either acting as a destabilising influence in the region, or interfering with trade. The use of proxies, such as Hezbollah, and interference with Iraq's political processes, are examples of Iran's willing to influence other Middle East states. Iran's nuclear programme is the most vexing concern of the international community. This, with Iran's emerging A2/AD strategy, is causing the most angst.

Iran and Israel have not always been so antagonistic towards each other. The rise of fundamentalists, such as Mahmoud Ahmadinejad, has changed Iran's view of Israel, and is seen as the main driver for Israeli concern.[1115] At writing Ahmadinejad, was the president of the Islamic Republic of Iran; Ahmadinejad is certainly not opposed to stoking the flames with his provocative rhetoric regarding the US, its allies, in particular, Israel.[1116] Domestic instability within a number of Middle East states is creating further anxiety. The events of 2011-2013 have highlighted the fragility of some Middle East regime's existence, and the inherent instability in this region. At the time of writing, the situation in Syria remains unresolved; it demonstrates the difficulties in orchestrating agreement within the UN's Security Council, and the limits of military power, against an adversary with a well-organised military, particularly a highly effective IADS.[1117] Even if concerned nations chose to take direct action, interdiction in Syria would possibly cause a reaction by that country

[1115] Dalia Dassa Kaye, Alizera Nador, and Parisa Roshan, *Israel and Iran: A Dangerous Rivalry*, Santa Monica, CA: RAND Corporation, 2012, p.x-xi.

[1116] David E. Thaler and others, *Mullahs, Guards, and Bonyads: An Exploration of Iranian Leadership Dynamics*, Santa Monica, CA: RAND Corporation, 2010, p. xi.

[1117] For an assessment of Syria's IADS capabilities, see Sean O'Connor, 'Strategic SAM Deployment in Syria', *Air Power Australia,* (2010), http://www.ausairpower.net/APA-Syria-SAM-Deployment.html, (accessed 3 February 2012).

and Iran, which would threaten to embroil the rest of the Middle East and consequently, the US and its allies.[1118]

Natural resources feature in the power plays between potential antagonists.[1119] The importance which oil plays in the politics of this part of the world is fundamental to how much outside states desire, or are prepared to become involved in, keeping the *status quo*, or deterring any unreasonable actions by belligerent states.[1120] Access to water is also a vital area of concern in the Middle East, and a cause of friction, with potential for conflict. Llan Berman and Paul Wihbey, writing in *The Institute for Advanced Strategic & Political Studies,* examined the increasing crisis over water in the Middle East:

> ….water resources are plummeting. While representing 5% of the total world population, the Middle East & North Africa (MENA) region contains only 0.9% of global water resources. The number of water-scarce countries in the region has risen from 3 in 1955 (Bahrain, Jordan and Kuwait) to 11 by 1990 (with the inclusion of Algeria, Israel and the Occupied Territories, Qatar, Saudi Arabia, Somalia, Tunisia, the United Arab Emirates and Yemen). Another 7 are anticipated to join the list by 2025 (Egypt, Ethiopia, Iran, Libya, Morocco, Oman and Syria).[1121]

Although access to oil and the shortage of water will remain potential conflict points, it is the Iranian dynamic, which is likely to remain the West's focus for some time. Iran is a rising power in the Middle East and a long-term challenge to US regional interests. The ruling elite within Iran perceive it as the natural leading power of the region, even of the Muslim World. Although Iranians are Persians, not Arabs, they certainly see themselves as the superior peoples in the Middle East. Graham Fuller, in *The Center of the Universe: The Geopolitics of Iran,* writes:

> Every Persian knows that there has been a Persia for nearly three millennia. The historical personality is deeply rooted. Persians have no doubt that Persia is a superior culture – far superior to the Arabs whom Persians historically perceived as crass Bedouin of the desert, "eaters of lizards", lazy and unversed in the ways of civilization…[1122]

Iran's sense of pride and importance is influenced by a number of factors, not least its feelings of victimisation and insecurity arising from historical exploitation by outside powers.

[1118] For a useful analysis of the symbiotic relationship between Syria and Iran, see Dawn Bartell and David Gray, 'Conflict in Syria and the Opportunity to Reduce Iran's Regional Influence and Iran's Threat to the International Community', *Global Security Studies* 3, no. 4, 2012, pp.136-147.

[1119] For a view on how important access to resources will be in the coming decades, particularly the importance of Middle East supplies, see Michael Klare, *Resource Wars: The New Landscape of Global Conflict*, New York: Owl Books, 2006, pp.5-26.

[1120] *ibid.,* pp.51-78.

[1121] Llan Berman and Pual Michael Wihbey, 'The New Water Politics of the Middle East', *The Institute for Advanced Strategic & Political Studies*, 1999, http://www.iasps.org/strategic/water.htm, (accessed 5 October 2011).

[1122] Graham E. Fuller, *The Center of the Universe: The Geopolitics of Iran*, Boulder: Westview Press, 1991, p.17.

This perception is still an important issue in determining and driving Iran's strategic doctrine and view of its place in the world.[1123] Britain, and France to a lesser extent, are considered Iran's original nemesis; this is largely due to the part that both countries played in dividing the Middle East up after World War I, and British interests in Iranian oil reserves.[1124] Iran now views the US and Israel as its main adversaries, and as threats to the regime's survival.[1125] Iran may see itself as the dominant force in the Middle East, however, Saudi Arabia's role in the region is fundamental, and its significance to the stability of the global economy is essential to how future international relations will develop. Conversely, Saudi Arabia views its status as the Middle East's centre of power and influence, and its relations with Iran as a likely flashpoint. Growing tensions over Iran's nuclear programme, and the elimination of Iraq as the main regional counterbalance, guides Saudi Arabia's relations with Iran.[1126]

Iran was traditionally ruled by a dynasty of Shahs (King of kings, or Emperor), with the last being Mohammad Reza Pahlavi, from 1941 to 1979.[1127] The 1979 revolution resulted in a referendum, with 97 percent Iranians supporting the establishment of an Islamic Republic.[1128] The Constitution of the Islamic Republic of Iran was finalised after the 1979 revolution. It stipulates that Iran is an Islamic Republic and that the teachings of Islam are the basis of all political, social, and economic relations. Constitutionally, the Supreme Leader has overall authority; he is chosen by the Assembly of Experts, an elected body of 83 religious scholars. Ayatollah Ali Khamenei, the current Supreme Leader, is the Commander-in-Chief of the armed forces, having ultimate decisions on military matters.

[1123] Thaler and others, *op. cit*., p.xii.

[1124] The British/French Sykes-Picot agreement has been a major factor in why there is so much division within countries such as Syria, Lebanon and Iraq, and also antipathy towards the British and French – see James Barr, 'A Line in the Sand: British-French Rivalry in the Middle East 1915-1948', *Asian Affairs* 43, no. 2, pp.237-252. In 1935, Reza, the Shah, tried to annul the Anglo-Iranian Oil Company's concession, but was forced to extend its concession for thirty years. In 1951, Iran's Prime Minister, Mohammed Mosaddriq, nationalised the Anglo-Iranian Oil Company – see Arthur Goldschmidt and Lawrence Davidson, *A Concise History of the Middle East,* Eight Edition, Cambridge, MA: Westview Press, 2006, pp.239, and 311-312.

[1125] An example of how much the British were disliked was illustrated, when, through the 1930s, German engineers were favoured ahead of British technicians, despite the fact that most Iranians thought little of the German fascist regime – see Michael Axworthy, *Iran: Empire of the Mind - a History from Zoroaster to the Present Day*, London: Penguin Group, 2007, p.233.

[1126] Richard Heydarian, 'Iran-Saudi Relations: Rising Tensions and Growing Rivalry', *Foreign Policy in Focus,* http://www.fpif.org/articles/iran-saudi_relations_rising_tensions_and_growing_rivalry, (accessed 12 July 2011).

[1127] For the background on the rule of Mohammad Reza Shah and the rise of Ayatollah Ruhollah Khomeini, until the Shah left the country on 16 January 1979, and Khomeini returning on 1 February, see Axworthy, *op. cit*., pp.244-263.

[1128] *ibid*., p.268.

The Constitution provides for a President to act as Chief Executive for a term of four years.[1129]

The Iranian political and domestic system is one in which the informal outdoes the formal, power and influence derive as much from personality as from position. Since the death of Khomeini, a number of key individuals have dominated the political elite in Iran, the first and foremost being Ayatollah Khamenei.[1130] Khamenei is the most powerful and influential individual in Iran, and while tacitly supporting Ahmadinejad with his stance against the US and the West, will only do so as long as the risks of confrontation are contained.[1131]

The 2009 Iranian presidential election and its aftermath proved to be a seminal event in the political evolution of the Islamic Republic. Perceived as a rigged election by the opposition, widespread protests resulted. The unrest upset an already unstable balance between advocates of the Constitution, with those who believed that the Islamic character of the regime is sacrosanct.[1132] Ahmadinejad's handling of the economy and sanctions have not helped.[1133] Mark Lynch, in *The Arab Uprising,* views, 'Iran's botched 2009 elections [as] the single greatest reason for its declining appeal to an Arab public that defined antidemocratic regimes as the enemy'.[1134] The opposition's position within Iranian society has not diminished. The nature of the opposition in Iran contains elements that oppose the Presidency of Ahmadinejad, the rule of Ayatollah Khamenei as Supreme Leader, and the system of clerical rule as a whole. The regime's somewhat benign reaction against the opposition has produced a fragile stability; however, this is likely to be severely stressed in the coming years.[1135] At writing, Iran's 2013 elections were being conducted, the results of these are not commented on.

Iran has traditionally played a critical role in the Middle East, pushing rivalries with key states and extending support to others. Its influence is based on oil and gas wealth, its large population, its relatively substantial armed forces and aggressive, but effective, state security services. Its own perceived strength also means it is prepared to interfere with

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[1129] For a background on the Iranian leadership, see generally Thaler and others, *op. cit.*

[1130] *ibid.,* p. xiii.

[1131] For an examination of the political leadership in Iran, see Nikki R. Keddie, *Modern Iran: Roots and Results of Revolution*, New Haven: Yale University Press, 2006, pp.329-331.

[1132] Prof. Amin Saikal, 'The Roots of Iran's Election Crsis', *Survival: Global Politics and Strategy* 51, no. 5, 2009, p.91.

[1133] Alizera Nader, 'Influencing Iran's Decisions on the Nuclear Program', in *Sanctions, Statecraft and Nuclear Proliferation*, Etel Solingen (ed), Cambridge: Cambridge University Press, 2012, p.224.

[1134] Mark Lynch, *The Arab Uprising: The Unfinished Revolutions of the New Middle East,* New York: Public Affairs, 2012, p.205. As previously defined, Iranians are not Arabs, but Persians, however, Arab peoples, in general, follow intensely the Iranian political scene.

[1135] *ibid.*

other states' domestic politics.[1136] Iran has extremely close ties with Syria's Assad regime and the Lebanese Shi'a party, Hezbollah, and some influence with Palestinian groups such as Hamas. Iran and Syria are most certainly close allies, with Syria acting as a conduit for weapons, funding and training for Iranian-backed militant groups, such as Hezbollah.[1137]

Iran's influence in the area and the wider Arab world is based largely on its religious and cultural links with Shi'a alliances. Always present, tension between Iran and Saudi Arabia means it is possible that Iran's Shi'a majority may align with, or encourage Saudi's Shi'a minority to rise up, particularly if provoked by an attack from Israel, for example.[1138] Protests by Saudi's Shi'a minority in November 2011 highlighted the effect that the 2011 'Arab Spring' has had in many Middle East countries.[1139] The events of 2011 have highlighted the limits of US influence and increased Israel's isolation. If the protests that resulted in the overthrow of governments in the Middle East in 2011 spread to Saudi Arabia, it is almost certain that the West will need to react, drawing in other Middle Eastern states, including Iran.[1140] It is likely that, longer-term, Iran fears the emergence of stable, moderate Arab states, which could threaten its influence. Under conditions of slow change or prolonged chaos, however, Iran should be able to influence events in its favour, which is a concern to some US and Israeli analysts.[1141]

<u>Iran's Nuclear Programme</u>

The UK's DCDC believe that: 'Iran is likely to become the most powerful state in the Middle East, although her rise to prominence will be contested…[Iran] is likely to shed her pariah status and be treated with degree of *realpolitik* by the international community'.[1142] This may be difficult to envisage at present, but is not an unreasonable analysis, when Iran's nuclear ambitions, and the reasons for them, are considered. It is Iran's nuclear programme, which is currently focusing the international community. Many Middle East states are also concerned about Iran's nuclear programme. If Iran successfully acquires a nuclear weapons capability, then other states in the region may decide that they also need

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[1136] Keith Crane, Rollie Lal, and Jeffrey Martini, *Iran's Political, Demographic, and Economic Vulnerabilites*, Santa Monica: RAND Corporation, 2008, p.2.

[1137] For a view on the dynamics between Iran, Syria and Hezbollah, see Rola El Husseini, 'Hezbollah and the Axis of Refusal: Hamas, Iran and Syria', *Third World Quarterly,* vol. 31, no. 5, pp.803-815.

[1138] See generally, Helen Chapin Metz (ed), *Saudi Arabia: A Country Study*, Washington: GPO for the Library of Congress, 1992.

[1139] For an analysis of rise of the 'Arab Spring', see Prof. Hamid Dabashi, *The Arab Spring: The End of Postcolonialism*, London: Zed Books, 2012, pp.17-40.

[1140] *ibid.*

[1141] Kaye, Nador, and Roshan, *op. cit.,* pp.1-2.

[1142] DCDC, *Strategic Trends Programme: Global Strategic Trends - out to 2040,* p.56.

to develop or acquire such weapons as a counterbalance. Although its nuclear programme is, according to Iran, solely for peaceful purposes, this is contested by the US, Europe, Israel and others.

Whether Iran requires nuclear reactors for power generation is debatable, however, the fact remains, under international law, it is perfectly entitled to have these for peaceful purposes.[1143] Unclassified evidence that Iran has a nuclear weapons programme has been sparse. Nonetheless, in November 2011, experts from the International Atomic Energy Agency presented convincing evidence that Iran is exploring ways to build a nuclear weapon. They confirmed that Iran has enough fissile material to build four nuclear bombs should it further enrich the uranium in its stockpiles. The report concluded that Iran is researching how to construct a nuclear weapon, but is not actively building one.[1144]

In December 2011, Leon Panetta, the US Defense Secretary, stated that Iran could build a nuclear weapon in less than a year, prompting speculation about an imminent military strike. This has obviously not happened, but importantly, indicating the measures the US was prepared to take, Panetta warned that the US was ready to use all options: '..we have to keep all options on the table…clearly there are those areas that for us are red lines. Number one, we cannot allow them to develop a nuclear weapon…'.[1145] In 2010, in testimony to the US House Committee on Foreign Affairs, William Burns, the Deputy Secretary of State probably best espoused the US stance:

> A great deal is at stake, for all of us. A nuclear-armed Iran would severely threaten the security and stability of a part of the world crucial to our interests and to the health of the global economy. It would seriously undermine the credibility of the United Nations and other international institutions, and seriously weaken the nuclear nonproliferation regime at precisely the moment when we are seeking to strengthen it. These risks are only reinforced by the wider actions of the Iranian leadership, particularly its longstanding support for violent terrorist groups like Hizballah and Hamas; its opposition to Middle East peace; its repugnant rhetoric

[1143] Roger Howard, *Iran in Crisis? Nuclear Ambitions and the American Response*, London: Zed Books Ltd, 2004, pp.97-98. Iran argues that it requires nuclear power for future needs, partly due to environmental and energy security concerns – see, Ghasem Ghorbani Rostam and Ali Safari, 'The Necessity of Nuclear Power in Iran', *International Journal of Engineering* 6, no. 6, 2012, pp.286-289.

[1144] International Atomic Enegry Agency, 'Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the Islamic Republic of Iran, Gov/2011/65', 8 November 2011, http://www.iaea.org/Publications/Documents/Board/2011/gov2011-65.pdf, (accessed 19 August 2012). For a detailed analysis on whether Iran possesses a nuclear weapons programme, see Bart Smedts, 'Iran's Nuclear Programme: Civil and/or Military Goals', *Defense & Security Analysis* 28, no. 3, 2012, pp.213-235.

[1145] Leon E. Panetta, US Secretary of Defense, 'U.S. Department of Defense, 12 January 2012, http://www.defense.gov/transcripts/transcript.aspx?transcriptid=4957, (accessed 4 August 2012).

> about Israel, the Holocaust, 9/11, and so much else; and its brutal repression of its own citizens.[1146]

Michael Herzog, a Senior Fellow at the Washington Institute for Near East Policy, and former Chief of Staff to Israel's Minister of Defence, emphasised Israel's position:

> Israel perceives a nuclear Iran as a potentially existential threat. The possible combination of extreme Islamism, a messianic leadership calling to "wipe Israel off the map" and nuclear weapons, is deeply sobering…A nuclear Iran will overshadow the calculations of regional actors, trigger a regional nuclear arms race, destroy the non-proliferation treaty, and increase the danger of miscalculation towards a nuclear crisis.[1147]

The greatest concern in the near term would be that an unstable Iranian-Israeli nuclear rivalry could emerge, with a significant risk that either side would launch a first strike on the other, despite the consequences. Over the longer term, Saudi Arabia and other states in the Middle East might pursue their own nuclear capabilities, raising the possibility of a highly unstable regional nuclear arms race.[1148] However, this may not cause the effect that some predict; nuclear proliferation has not generally been as widespread as initially forecast.[1149] For example, North Korea's possession of nuclear weapons has not pushed Japan to obtain any, at least yet. However, if this type of arms race ensued, it would be fundamentally different from the Cold War, when deterrence was essentially based between two states, the Soviet Union and the US. The interaction among three or more nuclear-armed powers would be more susceptible to miscalculation and escalation than a bipolar confrontation. Multi-polar systems are generally considered less stable, where situations can change quickly, upsetting the *status quo*.[1150]

Some analysts believe that there is the possibility that Iran might become less hostile towards Israel and the US, if it had its own nuclear deterrent.[1151] Others argue that Iran

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[1146] William J. Burns, 'Implementing Tougher Sanctions on Iran: A Progress Report: Statement before the Foreign Affairs Committee', 1 December 2010, http://www.state.gov/p/us/rm/2010/152222.htm, (accessed 8 October 2012).

[1147] Michael Herzog, 'Israel Is Wide Awake as Decision Time Approaches on Nuclear Iran,' *Financial Times*, 22 December 2011, p.14.

[1148] Eric S. Edelman, Andrew F. Krepinevich, and Evan Braden Montgomery, 'The Dangers of a Nuclear Iran: The Limits of Containment', *Foreign Affairs*, January/February 2011, p.67.

[1149] Shashank Joshi, 'The Permanant Crisis: Iran's Nuclear Trajectory', in *Whitehall Paper 79*, Professor Malcolm Chambers (ed), Abingdon: Routledge Journals, 2012, pp.104-105. See also, Peter Jones, 'Learning to Live with a Nuclear Iran', *Nonproliferation Review* 19, no. 2 2012, pp.209-210.

[1150] Edelman, Krepinevich, and Montgomery, *op. cit.,* p.72. See also, Office of the Director of National Intelligence, *Global Trends 2025: A Transformed World*, Washington, DC: US Government Printing Office, 2008, pp.ix-x, and 61.

[1151] For example, see Kenneth N. Waltz, 'Why Iran Should Get the Bomb: Nuclear Balancing Would Mean Stability', *Foreign Affairs* 91, no. 2, July/August 2012, pp.1-5. Waltz argues that a nuclear armed Iran would restore the military balance to the region, where Israel's possession of Nuclear weapons has upset the equilibrium for 40 years. Waltz cites China, India and Pakistan, as examples of states that have become much less verbally aggressive since becoming 'nuclear'.

does not regard nuclear weapons as crucial to its survival.[1152] There is also an argument that if Iran were to get nuclear weapons, the situation should be manageable. It is advocated that if clear no-cross lines were established with Iran and if contravened, retaliation would result. While this strategy worked during the Cold War, it is questionable if Iran would follow the same norms. Eric Edelman and others, from RAND, view this attitude as, '…far too sanguine…it rests on the questionable assumptions that possessing nuclear weapons induces caution and restraint, [and] that other nations in the Middle East would balance against Iran rather than bandwagon with it…'.[1153] Conversely, it is also reasoned that Iran's antipathy toward the US and Israel is so strong and so central to its leaders' legitimacy, that Iran will become more hostile once it has a nuclear arsenal, regardless of the consequences.[1154] Perhaps the greatest fear is that it is probable that the US, and its allies, would lose authority internationally, possibly even encouraging action by potential belligerent states and terrorist organisations.[1155]

Is the perceived view that the Iran leadership is so fanatical that it would use its nuclear arsenal outside the norms of self-defence and deterrence? Shashank Joshi, from RUSI, does not believe so, citing the examples of the Soviet Union and China, both of whom have a history of mass extermination against their own population, and other non-democratic actions, yet managed, and continue to manage, their nuclear deterrents within international norms.[1156] According to Dr Jonathan Eyal, Director of International Security Studies at RUSI: '…the debate about deterring a nuclear Iran is much more about the West and the risks it wishes to take, rather than about the price the country's neighbours may be required to pay…and the measures they may take to deal with the situation'.[1157] Eyal agrees with other analysts that it likely to become a multi-sided issue, in which each state has a different perception of threats and the resulting calculation of risk.[1158] Is this view too optimistic? Henning Duus, in *Comparative Strategy,* argues that a nuclear Iran would present the West with, '[an] unprecedented asymmetrical threat'.[1159] Duus's point is that

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[1152] Robert Baer, *The Devil We Know: Dealing with the New Iran Superpower*, New York: Three Rivers Press, 2008, p.111.

[1153] Edelman, Krepinevich, and Montgomery, *op. cit*., p.67.

[1154] Robert Danin views that a nuclear armed Iran would create an imbalance in the area, causing others to seek acquiring the same. It would also likely increase the incentive for Israel or the US to attack Iran – see, Robert Danin, 'Iran with the Bomb', in *Iran: The Nuclear Challenge*, Robert D. Blackwill (ed), New York: The Council on Foreign Relations, 2012, pp.51-59.

[1155] *ibid.*, p.56.

[1156] Joshi, 'The Permanent Crisis: Iran's Nuclear Trajectory', pp.84-85.

[1157] *ibid.,* p.85.

[1158] Dr Jonathan Eyal, 'Are We Able to Deter Iran?', *Royal United Services Institute*, 2012, http://www.rusi.org/analysis/commentary/ref:C4F74A24A1E361/, (accessed 4 April 2012).

[1159] Henning P. Duus, 'Deterrence and a Nuclear-Armed Iran', *Comparative Strategy* 30, no. 2, 2011. p.134.

Iran may use its nuclear deterrent, not as has traditionally been the case between the West and Russia or China, but within the context of a religious fulfilment of God's will.[1160] On the other hand, Ray Takeyh, in *Hidden Iran,* believes that, '…Iran's quest for nuclear weapons does not stem from irrational ideological postulations, but from a judicious attempt to craft a viable deterrent posture against a range of threats'.[1161] Takeyh argues that Iran is merely attempting to gain a position with nuclear weapons that will allow it to prevent attacks, such as chemical weapons used by Iraq in the 1980s; Israel, he believes, is not part of Iran's motivation.[1162] Peter Jones, writing in *The Nonproliferation Review,* has a different view; he argues there, '…are many reasons why Iran's elite groups may pursue a nuclear program, even at great cost. These reasons include: internal political wrangling for power among the different factions; national and regional prestige; and the opportunity for vast corruption that accompanies any large program…'.[1163]

There is a view that Iran does not require nuclear weapons in order to achieve its aims. Robert Baer believes, '…the Iranians see a nuclear bomb as nice to have but not crucial to their survival'.[1164] Baer views as odd that the West seems to be ignoring Iran's conventional weapons development, and is blinded by the worst-case scenario.[1165] Some experts believe that Iran will very soon be able to 'break out', that is make a dash to enrich enough weapons grade uranium for a nuclear device.[1166] Whether this is the case, or not, perhaps the antipathy towards Iran's obtainment of nuclear weapons requires realignment.

Negotiating with Iran is a complex task. Diplomacy will be absolutely crucial to any solution to Iran's nuclear position, whatever sanctions, or indeed force, is used.[1167] A growing realisation that it may not be possible to prevent Iran obtaining nuclear weapons has caused an audit of other options. One may be a containment strategy of extended deterrence. In July 2009, the US Secretary of State, Hilary Clinton, suggested, '…the US

[1160] *ibid.,* pp.134-144.

[1161] Ray Takeyh, *Hidden Iran: Paradox and Power in the Islamic Republic*, New York: Times Books, 2006, p.140.

[1162] *ibid.,* pp.140-146.

[1163] Jones, 'Learning to Live with a Nuclear Iran', p.202.

[1164] Baer, *op. cit.,* p.110.

[1165] *ibid.*

[1166] James Blitz, 'Time Runs out for Diplomatic Dance on Iran's Nuclear Plans', *Financial Times,* 18 February 2013, p.6.

[1167] Andrew Parasliti from IISS, argues that diplomacy will be fundamental to a solution to the Iran nuclear issue; see ,Andrew Parasiliti, 'Closing the Deal with Iran', *Survival: Global Politics and Strategy* 54, no. 4, 2012, pp.33-41.

could extend “a defense umbrella over the region”’.[1168] This policy could be immensely expensive, however, and would not necessarily be successful.

Sanctions

The US and other countries have applied a number of sanctions, attempting to force Iran into giving up its nuclear weapons ambition, but so far to no avail.[1169] US sanctions over the last 30 years have limited Iran’s ability to dominate the region, but they have singularly failed to influence leadership choices, or indeed, prevent the development of a nuclear programme. Indeed, some analysts believe that sanctions could backfire, and actually cause further intransigence.[1170] Russia and China are reluctant to support an increase in further sanctions. China remains opposed to economic sanctions that could harm its own economic interests, particularly its access to Iranian oil and gas. Are economic sanctions actually working? GDP per captia has fallen from US $4,589 in March 2011, to $3,366 in March 2013. However, some analysts believe that this is in part due to internal issues, and any change in Iran’s nuclear position will not improve the economic situation.[1171] Indeed, there is a belief that the current sanctions benefit the regime, while weakening those whom support reform.[1172] Robert Hunter, a former US Ambassador to NATO, currently a senior advisor at the RAND Corporation, believes that sanctions, ‘…undercut, politically, elements in Iran which would like the regime to change course. This is thus a time-buying option, with little realistic chance of working’.[1173]

Iran’s Strategy

Iran is pragmatic – it knows it cannot win a head-to-head war with Israel or the US. Yet it believes it can influence its own hegemony in the region by attempting to deny the safe access of shipping through the Arabian Gulf, and by making support bases unsafe from which to operate. Iran cannot win a military conflict with the US, but it can gain leverage by

[1168] Edelman, Krepinevich, and Montgomery, *op. cit*., p.74.

[1169] For analysis of the effectiveness of sanctions, see Richard A. Falkenrath, 'Prospects for a Negotiated Outcome', in *Iran: The Nuclear Challenge*, Robert D. Blackwill (ed), New York: Council on Foreign Relations, 2012, pp.21-27.

[1170] Ray Takeyh and Suzanne Maloney, 'The Self-Limiting Success of Iran Sanctions', *International Affairs* 87, no. 6, 2011, pp.1311-1312.

[1171] Bijan Khajehpour, Alireza Nader, and Michael Adler, 'The Nuclear Issue: Why Is Iran Negotiating', *Woodrow Wilson International Center for Scholars: Middle East Program - Viewpoints* 21, February 2013, pp.1-3.

[1172] *ibid.*

[1173] Robert E. Hunter, 'Rethinking Iran', *Survival: Global Politics and Strategy* 52, no. 5, 2010, p.141.

threatening to close the Strait of Hormuz.[1174] This would have a detrimental effect on the supply of oil, with 35% of the world's seaborne oil, and a total of 20% passing through the Strait of Hormuz.[1175] Iran does not have a range of weapons capable of denying access totally. However, it does not need to, as by simply mining parts of the Strait of Hormuz, or threatening to do so, it would likely deter most civilian shipping. Added to this, Iran could threaten to use its BM, ASCM, and other military assets, such as manned fast-boats and jet-skis, midget and diesel attack submarines and low-signature UAV, to target any shipping within reach.[1176] Although lacking targeting accuracy, these would still likely create enough doubt, forcing huge efforts to counter this threat. Iran's ability to fight an asymmetric war could push the US into taking major military action, which would escalate tensions, at the very least.[1177] Andrew Krepinevich judges, '…that the Persian Gulf…could become a no-go zone for the U.S. Navy'.[1178] In effect, Iran's doctrine is an AD/A2 strategy. While airfields in allied states, such as the United Arab Emirates, could be utilised to support US backed operations against Iran, should these be targeted or civilian centres threatened with retaliation, then maritime forces, or bases further away from the centre of gravity than initially planned, may be the only viable option from which to launch operations. The US is currently focused on China's A2/AD threat, but it also needs to address Iran's emerging A2/AD strategy. According to Mark Gunzinger from CSBA, 'Iran is pursuing capabilities that would allow it to deter, delay, or prevent timely US operations in the Persian Gulf, giving Iran the breathing room it would need to commit acts of aggression or coercion in the region'.[1179] While Iran may currently lack the military capability to execute such a strategy effectively, its efforts strongly suggest its objective is to acquire such capabilities as quickly as possible. To counter such threats would require the same capabilities required to counter China's A2/AD doctrine. Gunzinger and Douherty consider, 'Future air dominance systems may very well include a large aircraft more akin to a true "fighter-bomber" that possesses the capability to operate over longer ranges and carry

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[1174] Alireza Nader, 'Will Iran Close the Strait of Hormuz?', *United States Institute of Peace: The Iran Primer*, 2 October 2012, http://iranprimer.usip.org/blog/2012/oct/02/part-ii-will-iran-close-strait-hormuz, (accessed 18 February 2013).

[1175] Estimated in 2011 – see U.S. Energy Information Administration, 'Iran Analysis', November 2011, http://www.eia.gov/countries/cab.cfm?fips=IR, (accessed 11 January 2013).

[1176] For an assessment of Iran's capabilities in denying ships passage through the Strait of Hormuz, see Editorial, 'Strait of Hormuz: Iran's Disruptive Military Options', *Strategic Comments - IISS* 18, no. 3, 2012, pp.1-3.

[1177] See Caitlin Talmadge, 'Closing Time: Assessing the Iranian Threat to the Strait of Hormuz', *International Security* 33, no. 1, 2008, pp.82-117.

[1178] Krepinvech, *op. cit.,* p.21.

[1179] Mark Gunzinger, 'Outside-In: Defeating Iran's Anti-Access and Area-Denial Threat', Washington DC: Center for Strategic and Budgetary Assessments, 2012, http://www.csbaonline.org/publications/2012/01/outside-in-operating-from-range-to-defeat-irans-anti-access-and-area-denial-threats-2/, (accessed 3 March 2012), p.2.

significant payloads of air-to-air missiles, anti-radiation air-to-surface missiles…and possibly [DEW]'.[1180]

Potential Military Action

Whether the US conducts strikes or Israel acts unilaterally anytime soon, or a coalition does in the future, will undoubtedly have repercussions throughout the Middle East, and further afield. If this happens, it is highly likely Iran's reactions would include an asymmetric campaign against any state that it deemed an aggressor.[1181] Israel's acceptance of the 'nuclear' Iran is highly unlikely. Israel sees its 'nuclear deterrent', not in the traditional sense that the West and the Soviet Union saw theirs during the Cold War, but more as a barricade, that it can hide behind, enabling it to conduct its military policies at will.[1182] Even if Israel were to conduct a unilateral strike against Iran's nuclear infrastructure, it might set the programme back, but probably only for a short period. The US is the ultimate guarantor of Israel, and although the US could use significantly more military capabilities, an attack might backfire.[1183] As much as many of the Gulf states fear Iran's intentions, they would prefer a solution that is not based on military force; they fear Iranian retaliation and, not least, the response of their own people, if it came to war.[1184] Edelman, and others, believe a strike, '…might enhance popular support for the regime…further strengthen Iran's determination to go nuclear, and trigger a costly retaliation against the [US and its allies] in the Middle East'.[1185] Frank Barnaby, from the Oxford Research Group, views that, 'Far from setting back Iran's nuclear programme, a military attack might create the political conditions in which Iran could accelerate its nuclear weapons programme'.[1186]

[1180] Gunzinger and Dougherty, *op. cit.*, p.87.

[1181] For analysis of the likely Iranian response, see Robert D. Blackwill, 'A U.S. Attack on Iran', in *Iran: The Nuclear Challenge*, (ed), Robert D. Blackwill, New York, NY: Council for Foreign Relations, 2012, pp.38-40

[1182] Jones, 'Learning to Live with a Nuclear Iran', p.209.

[1183] Yossi Melman and Meir Javedanfar, *The Nuclear Sphinx of Tehran: Mahmoud Ahmadinejad and the State of Iran*, New York: Carroll & Graf Publishers, 2007, p.200. A similar scenario was China's nuclear programme in the 1960s. Attacks on Chinese nuclear facilities were considered by the US, but the diplomatic costs, a possible failed attack, and a lack of certainty over whether a nuclear armed China would be unmanageable, meant no such operation was undertaken – see Friedberg, *op. cit.,* p.70. See also, Dong Sun Lee, 'US Preventive War against China', *Asian Security* 3, no. 2, 2007, pp.174-179. George Walden also discusses how close the Soviet Union came to conducting attacks, apparently seeking US approval to do so, but failing – see Walden, *op. cit*., pp.40-41.

[1184] Lynch, *op. cit*., p.206.

[1185] Edelman, Krepinevich, and Montgomery, *op. cit*., pp.78-79.

[1186] Frank Barnaby, *Would Air Strikes Work? Understanding Iran's Nuclear Programme and the Possible Consequences of a Military Strike,* Oxford: Oxford Research Group, 2007, p.2.

There have been 16 attacks against nuclear facilitates since 1942, and although these have prevented, or even stopped, nuclear weapons programmes, it is arguable whether the situation in Iran can be used as an equivalent example.[1187] Paradoxically, a strike against Iran's nuclear weapons facilities may sway support from some countries towards Iran's ambitions, or at least allow Iran to revamp its programme, unhindered by international agreements, or UN inspectors.[1188] Shashank Joshi believes, '…it is important to understand that a preventive war against Iran in the short-term could result in a more aggressive Iranian nuclear posture in the longer-term…constraining the West's future military options'.[1189] Joshi also views that although a nuclear Iran is undesirable, it is probably containable at an acceptable level of risk.[1190] A view that is gaining credence, and is certainly worth considering.

Summary

There are numerous opinions on the best strategies towards Iran, whether they are containment; engagement, or military confrontation; it is beyond the scope of this thesis to make a judgement. It is worth considering, however, as Robert Blackwill argues, dealing with the complexities of Iran's nuclear weapons programme cannot be compared with historical analogies, such as World War II, Korea or Vietnam. Blackwill advocates an assessment process that attempts to avoid possible unintended consequences. As an example, he cites the US embargo of oil to Japan in 1941, which was a major factor in Japan's decision to attack Pearl Harbour.[1191] It is, ultimately, Khamenei whom will decide whether Iran continues with its nuclear weapons programme.[1192] Perhaps the Iranian's themselves will pressure the regime's leadership to temper their nuclear ambitions.[1193] Nuclear armed or not, Iran's significance to international relations in the coming decades is unlikely to abate. Iran's aspiration to dominate the Middle East will require significant efforts by the international community in order to establish a workable stability in the region.

[1187] For a view on the efficacy of bombing Iran's nuclear facilities, see Sarah E. Kreps and Matthew Fuhrmann, 'Attacking the Atom: Does Bombing Nuclear Facilities Affect Proliferation?', *Journal of Strategic Studies* 34, no. 2, 2011, pp.161-187.

[1188] For an examination of the potential outcomes of airstrikes on Iranian nuclear facilities, see Robert Reardon, *Containing Iran: Strategies for Addressing the Iranian Nuclear Challenge*, Santa Monica, CA: RAND Corporation, 2012, pp.125-130. See also, Gregory Copley, 'Israel and Iran: Still No War in Sight', *Defense & Foreign Affairs Strategic Policy* 40, no. 3, 2012, p.9.

[1189] Shashank Joshi, 'Is a Nuclear Iran as Dangerous as We Think?', *Royal United Services Institute*, 2012, http://www.rusi.org/analysis/commentary/ref:C4F4BA65E76604/, (accessed 5 April 2012).

[1190] *ibid.*

[1191] Robert Blackwill, 'How to Think About the Iranian Nuclear Problem', in *Iran: The Nuclear Challenge,* Robert Blackwill (ed), New York: The Council on Foreign Relations, 2012, pp.65-66.

[1192] Nader, *Influencing Iran's Decisions on the Nuclear Program*, p.222.

[1193] *ibid.,* p.214.

To do this requires a force structure offering a credible capability to deter, or to act with force if necessary.

The means by which an alliance targets appropriate Iranian C2 and IADS nodes may well fall to forces positioned at distances that require the ability for airborne assets to have the qualities of endurance and reach, with high survivability. These forces may be obliged to operate to the east of the Strait of Hormuz, or from the Western Mediterranean. The same requirements for systems that can operate in the Western Pacific could be utilised against Iran. The likely ability of Iran to deny access to the Arabian Gulf and viable operating bases will force military systems to operate from distances that require weapon systems with range and endurance. Gunzinger and Dougherty believe the US should seek new air dominance capabilities that would be less dependent on close-in bases and AAR. They recommend developing long-range bombers and carrier-based unmanned aircraft, observing that, '…forces that require very large close-in theatre footprints, are only suitable for operations in permissive and semi-permissive areas, or are limited to performing "niche" missions, may be candidates for reduced funding'.[1194] Air-breathing systems capable of operating at range, while enduring for significant periods, will be required; these systems will be necessary to conduct all combat air tasks, including, ISTAR, SEAD, strike, and counter-air. UCAS developed to complete all of these tasks would help to enhance the capabilities of those states responsible for containing the Iranian threat. These same systems will have efficacy in any scenario that requires access by forces denied access to their normal operating bases and platforms.

Both land- and sea-based air power will be an essential element of any conflict in the Arabian Gulf, or for that matter, other areas of the world requiring interdiction other than from a nation's own homeland bases. Within these scenarios, efficient generation of a large number of sorties will be crucial to accomplishing the required operational objectives. To a lesser extent, but certainly with some effect, Iran could use the same A2/AD doctrine as China. In the confines of the Arabian Gulf, and in those states that would support a US led alliance, the mere threat of massive retaliation from Iranian weapon systems would probably cause pause for thought by a US alliance, at the very least. Would the US risk a CSG in an Arabian Gulf conflict, even if the chances of it being successfully targeted were small? In such scenarios, the critical nodes of a force's counter-air capabilities require serious auditing.

[1194] Gunzinger and Dougherty, *op. cit*., p.98.

Conclusion

'The only security upon which sound military principles will rely is that you should be master of your own air'.[1195] Churchill's dictum remains extant. UAS are currently assuming roles in air power that have traditionally been undertaken by manned aircraft, at least in permissive environments. Future warfare could see UCAS, the next evolution of UAS, undertaking the tasks and accepting most of the risks in high threat scenarios that have previously been the responsibility of military aviators. UCAS have the potential to offer a revolutionary new set of options, with enormous long-term payoffs to air power in terms of persistence, endurance, tactical deterrence and affordability. The context in which these systems would be used is fundamental to their developmental path. Although the military capabilities of future threats to international security should be adequately assessable, the intent of these nations remains less easy to predict. An understanding of where these threats are likely to come from is essential; any specious assumptions will lead to erroneous conclusions, in turn, potentially leading to the wrong procurement decisions. Some countries struggle to balance their aspirations with the threat of political and economic disintegration; it is relationships with these countries that are likely to dictate the frequency and severity of future military challenges. Future conflicts will probably range from peace keeping and policing roles, to minor inter-state warfare, with the potential for large interstate warfare. Identification of these possible adversaries is realistically achievable; how they are deterred and, if required, defeated, is not so easily accomplished.

The UK's DCDC views the era out to 2040 to be a time of transition: 'Out to 2040, the focus of global power will move away from the US and Europe towards Asia…[the US] is likely to remain the pre-eminent military power…in political, economic and military terms, she is likely to be increasingly constrained as others grow in influence and confidence'.[1196] China is currently the World's No 2 economic power, and is likely to overtake the US power by 2030.[1197] There is also a view that China will reach technological parity with the US, sometime between 2040 and 2050.[1198] Both of these paradigm shifts are aligned with China's desire to become a major military power, able to influence the *status quo* in the Western Pacific, forcing its hegemony in the region. This will make China the centre of gravity for the foreign and military policies of the US and others in the coming decades. While the US does not view China as an existential threat to the US mainland, it believes that it poses a threat to stability in the region. China's developing A2/AD doctrine will force

[1195] Langworth, *op. cit.*, p.205.

[1196] DCDC, *Strategic Trends Programme: Global Strategic Trends - out to 2040*, p.30.

[1197] National Institute of Economic and Social Research, *op. cit*., p.F2

[1198] Cheung, *op. cit.,* Section 1, p.19.

states, especially the US, to mould foreign and military policies to militate against China gaining dominance in the Western Pacific and the South China Sea. Not only does China wish to bring Taiwan into its sphere of influence, it also desires to hold sway over the natural resources lying beneath the South China Sea, and is also hedging against access being denied through the Strait of Malacca, through which most of its oil supplies transit. For many of the same reasons, the US, its allies and others, do not wish China to gain strategic dominance in this part of the world. The Middle East, with Iran at its centre, will also test international relations. Iran is also developing a strategy of A2/AD. China and Iran's A2/AD doctrine will likely force the US and its allies to operate from land bases and aircraft carriers at greater ranges than those currently planned. The development of ASBM, such as the DF-21D, and other weapon systems capable of pinning forces down at ranges that make current weapon systems unviable in deterring aggression in these regions, requires inspired evaluation. Air systems, *inter alia*, which are capable of operating at ranges outside of these threats, potentially unsupported, are necessary. At whatever distances from bases, against an adversary with an air defence capability, control of the air will continue to be a fundamental prerequisite for all conventional military operations.

Powered unmanned aircraft have been operating almost as long as manned powered flight. Along with the trend towards single-seat aircraft operations, doctrine and tactics have evolved to take advantage of the transformation evolution that technological advances have allowed manned flight to utilise. Other than the actual act of flying an aircraft, historically, navigation has been deemed critical to mission success. Navigation accuracy and the precision of weapon delivery, both air-to-air and air-to-ground, is, currently, the predominant requirement for combat air power. The Gulf Wars of 1991 and 2003, and COIN operations in Afghanistan and post-war Iraq, have demonstrated the vital role that precision weapon delivery plays in modern warfare. The primacy of navigation, and all that the mastery of it brings, is now firmly established as the priority of any nation wishing to have, and use effectively, a military force. As technology has developed, the role of the navigator, and other associated airborne professions, has become less crucial. Using the same rationality, the fact that pilots have traditionally been required to fly aircraft that facilitate achieving the requisite military task, should not be a driver for future doctrine, tactics, or procurement. Technology now allows greater time, effort, and resources to be focused on systems that will not require a human interface in an aircraft, or potentially, even monitoring weapon systems.

Existing UCAS programmes focus on detecting and destroying TST, utilising ISTAR and SEAD roles – the air-to-surface part of the counter-air task. Most military forces consider the air-to-air component of counter-air warfare, a true TST issue, as the main pillar of air power, or at least, 'the first amongst equals'. Significantly, there is a paucity of research into the air-to-air capabilities and requirements for future UCAS. The importance that situational awareness plays in warfare, particularly in control of the air, is vital. From World War I, through to modern air warfare, situational awareness has proven to be the key enabler in gaining control of the air; pilots, and other aircrew and personnel, have of course been vital, but would be ineffective if they did not possess situational awareness. NEC is pivotal in establishing consistent and reliable battlefield situational awareness. Along with the negating portion of the kill chain, this is the critical node in all the domains of warfare.[1199] Could the same systems that give the F-22 Raptor and future F-35 JSF operators' situational awareness be utilised by UCAS? Could UCAS properly see and sense what an adversary is doing now, not just where it is? Using NEC to gain situational awareness will allow an integrated UCAS to take the fight to an adversary, at ranges that are not currently obtainable by manned counter-air systems.

The gun, and since the 1950s, AAM, have been used in aerial conflicts, however, there have been no known Western or Israeli air-to-air kills requiring classic air combat manoeuvring since the Vietnam War.[1200] This covers almost 40 years of military aviation - a significant portion of the total history of aerial combat. The utility of the air-to-air gun has to be questioned. 'It will never be required' cannot be guaranteed, however, the question of whether it is worth the cost of developing certain weapon systems and aircraft manoeuvrability, requires stringent examination.

If viewed dispassionately, there is nothing particularly difficult in conducting the air-to-air role, if situational awareness is adequate, and weapon systems are effective. It is relative, however; viewed as a three-dimensional chess game, air combat has stressed the capabilities of modern air systems and aircrew. Nonetheless, even in the most complex visual air-to-air engagements, there would be a finite number of possible decisions. If the 'unknowns' are 'known', it is essentially a case of completing a set of prescribed manoeuvres and decisions, that, although complex at times, should be programmable. Situational awareness is the key. If only partial situational awareness exists, a logical pattern of actions should still be programmable. In any case, it is arguable whether visual air combat, requiring highly manoeuvrable aircraft, will be required by 2040.

Given any counter-air scenario, a human, with the correct training, being in the right frame of mind, and having the required skill and situational awareness, could make the correct

[1199] Notwithstanding that navigation accuracy facilitates both.

[1200] This is, for the purpose of this thesis, classified as sustained visual manoeuvring in order to achieve a kill, as opposed to visually acquiring an adversary, and then taking a shot, with little, or no, manoeuvring required. On some engagements, adversary aircraft have manoeuvred so aggressively to avoid being shot, that they have flown into the ground – see, for example, Craig Brown, *op. cit.,* pp.60-63.

decisions. Because most humans are affected physically when operating high-performance aircraft in dynamic and stressful environments, assimilating information is extremely difficult without taking some time to do so, and potentially making the wrong decision, or too late; if the process was automated to a level that did not require human input, then the outcome would probably be fundamentally improved. The days of fighter pilot versus fighter pilot in visual air combat may not be over, but they will surely continue to follow the trend since the 1980s.

To some, the term ‘autonomous’ is emotive. The author’s view is that UCAS would only truly be autonomous if communications links were lost, and then only in the sense that these systems will be operating in a highly automated mode, with no supervision by a human. UCAS would use the algorithms within their pre-programmed systems, using look-up tables that would contain all conceivable eventualities; computing processing technology should continue to advance, allowing systems to conduct operations to the level of a human, but faster and more accurately. AI programs, such as Agent software, could be used to aid the decision process, but only within a defined set of rules. Autonomous systems would not make random decisions without the constraints that would normally be placed on humans. Data fusion of information collated through NEC, allowing the employment of kinetic effects, such as AAM or DEW, could be utilised on UCAS, or manned systems. With a high level of automation/autonomy, and situational awareness, the ‘system,’ could make all the appropriate decisions on required tactics, leading to successful engagements. Development of these systems should allow the appropriate effect to be obtained before the visual arena is entered – or at least to an extent that does not warrant development of close visual combat systems that require the air vehicle component to be highly agile. The requirement for what is currently known as a ‘knife fight in a telephone box’ by fighter crews, would be negated by the use of HOBS weapon systems with a high kill probability, whether AAM or DEW, aligned with NEC.

The effect that political, legal and ethical issues of using UCAS might have upon decision makers is an important consideration. This should not be underestimated, particularly in terms of politicians’ willingness to deploy such systems at little, if any, risk to their own military personnel. Although ROE constraints and political necessities may initially militate against full autonomy, the development of AI and HMI technology should offer a level of integration enabling a greater degree of certainty when conducting CID and CDE, than that of HITL systems. It would also allow missions to be planned and then executed using on-board decision making – with a HOTL monitoring the system and taking action only when necessary, and perhaps autonomously, if this is deemed desirable.

The LOAC calls for the responsibility of a human to be in the loop when decisions are made for release of weapons. The 'Nuremburg Principle' requires that someone will always be held accountable for an action that is taken that falls inside or outside of international law – that is, they are legally and morally accountable. Is it against the LOAC if UCAS are used without a human at least 'on the loop'? If responsibility is taken within the command chain, at all levels of decision-making, then no laws are broken. It could be argued that it is the software programmers who write the code for UCAS that are ultimately responsible. However, this is not the situation with extant weapon systems that are autonomous (highly automated). Air-to-surface missiles, SAM, cruise missiles, and AAM, are all examples of weapon systems that have this capability. Military commanders and politicians have satisfied themselves that the level of risk that these weapons pose in causing collateral damage is acceptable within the LOAC. The same logic would apply to UCAS. It is straightforward – if the legal criteria could not be met, then UCAS would probably not be utilised autonomously.

It was fundamental to ensure that this thesis had merit. The questionnaire used, established that the research methodology was appropriate, and that the subject warranted investigation. Many of those interviewed had relevant experience in counter-air operations. Ninety-eight percent believed UCAS could gain control of the air by 2040. These are pilots, navigators, and counter-air specialists with an understanding of all the relevant strands and many vagaries that the fundamentals of air-to-air combat have traditionally entailed. It seems counterintuitive, but none was tempted to protect the man in the cockpit; none had the 'pilots/aircrew are gods' attitude which has prevailed in air forces around the world, ever since aircraft were first used as weapons of war. Eighty-six percent of interviewees have no ethical concerns with the use of UCAS. This does not mean, however, that consideration is not required when developing training for personnel, taking into account a potential lack of understanding of air power, if these personnel have not themselves been immersed in the philosophy of warfare, or indeed, in combat operations. There may also be a risk of detachment when authorising weapon release, perhaps leading to a lack of emotional connectivity with the battlespace. These aspects will require particular attention by military leaders.

Persistence and endurance are important constituents of air power, allowing weapon and sensor effects capabilities to be maintained for long periods. Autonomous air-to-air refuelling, potentially with unmanned tankers, together with advanced power sources will enhance this capability. These technologies will take time to acquire, but should be within the reach of the Western defence/industrial apparatus by 2030-2040. The physiological constraints faced by aircrew today are unlikely to be mitigated in the coming decades. Separating aircrews from their platforms is a factor in increasing range and endurance, not so much in allowing more fuel to be carried, but by at least negating the requirement to sustain a human for periods that are considered unviable. Similar to manned aircraft, a future UCAV may use stealth characteristics and defensive measures to penetrate hostile airspace; EA capabilities would also be a fundamental requirement. However, although UCAS could deploy over great distances and with a reduced logistic chain, their operating tempo may stretch any manned airborne supporting systems. If the cost of UCAS means that these systems are treated as HVAA, the result may be that manned fighters, themselves valuable airborne assets, are required to protect them, constraining these UCAS to operate within range of manned fighters, thereby negating any advantage that these systems offer. It is important, therefore, that UCAS are capable of operating independently of other HVAA, with a high chance of survival; that is, UCAS should be able to gain and maintain control of the air.

The author's research indicates that an unmanned counter-air vehicle will need to have some of the characteristics of the current USAF's F-22 Raptor – namely, EA and stealth technology tailored to combat X-band (fighter) radars, aligned with high-speed and height capabilities. A UCAS, or any manned system for that matter, would not require being as manoeuvrable. The effectors for gaining control of the air combine the C2, NEC, sensors, aircraft, weapon systems, personnel, and the logistics chain. Effective ISTAR, SEAD, and general air-to-surface missions will require all of these current enablers, which have proven to be effective in most conflicts since the Vietnam War. There is doubt, however, in the effectiveness of some current air-to-air enabling assets - that is, the sensors and weapons currently utilised. AAM have not fulfilled their initial promise. While statistics since 1991 show that the kill probability of air-to-air systems have significantly improved, these have not developed to the extent that they offer a guarantee of winning an air-to-air battle against a peer adversary. Future negation systems offering a high kill probability are required. When countering an adversary with numerical superiority, the quality of own weapon systems, aircrew training and C2/NEC are paramount. When opposing an adversary that has both superiority in numbers and in weapon systems, and whose training and C2/NEC is adequate, then control of the air cannot be guaranteed. Whether there will be major conflicts between nation-states in the coming decades can be debated. However, at the very least, force structures and capabilities will be required to deter potential aggressors.

The best way to fight a war is to prevent it happening. Diplomacy, sanctions, and ultimately the threat of force, are all traditional tools in international relations. Future conflicts between major powers may follow the same deterrence route. Conflict may be averted if it is clear one side has a major strategic advantage over another. However, the deterrence and escalatory policies of some states may not follow currently accepted norms. The

A2/AD strategies that countries such as China and Iran are evolving will test current Western doctrine and strategy, and, not least, the planned manned air-breathing weapon systems envisaged to implement policy. These strategies will strain the capability of seaborne forces to operate within current planned distances of adversary centres of gravity and target sets. Land-based forces may face similar constraints. Systems that are capable of operating from ranges and for periods, hitherto not required, are needed to counter these new emerging strategies, and that also offer a potent deterrence; as Bernard Brodie observed: 'It is a truistic statement that by deterrence we mean obliging an opponent to consider, in an environment of great uncertainty, the probable cost to him of attacking us against the expected gain thereof'.[1201]

The potential of UCAS conducting missions totally autonomously, semi-autonomously, or as part of a swarm, controlled or monitored by a single pilot in a fighter, or operator in a large aircraft, such as an AWACS, or from a stationary C2 node, should be assessable. This will take time and funding, with technological advances informing decisions based on a series of connected trials, programmes, and academic and scientific analysis. Until novel systems, not currently conceived, are available, it will fall to air-breathing systems to take the fight to the enemy. Ultimately, it may be possible for a large COMAO formation of combat and support aircraft, combining manned aircraft and UCAS, or made up entirely of UCAS, to operate together or autonomously. This autonomy may permit quicker and more accurate decisions, enhancing the probability of survival, while achieving the desired mission objectives. UCAS would use automated flight and mission management systems, which could also be utilised by manned aircraft. If these management systems reach the capability that allows them to be trusted to an acceptable level, it is axiomatic that the HITL would not be required, for other than legal considerations. Using the author's autonomy levels, which are based on NASA's FLOAAT and the DERA PACT concepts, Level-Four would be the normal envisaged operating mode, with a HOTL only intervening if required. Level-Five, giving full autonomy, would be implemented if communications links were lost, and the importance of the mission was deemed crucial enough to warrant the potential risks that this may involve.

A radical approach is required, if current strategic doctrine remains extant, with the emphasis on the 'AirSea' concept for counter-A2/AD warfare. Against potential adversaries with this strategy, current and planned weapon systems will be tested by the necessity to operate at extended ranges and with adequate persistence. It is the economics and operational effectiveness of such systems that are likely to affect decisions on procurement

[1201] Brodie, *The Anatomy of Deterrence*, p.11.

and capability. Although there is understandable doubt as to their future efficacy, development of UCAS may reach the stage where it can be demonstrated to commanders, both military and political, that there are no adverse risks. With situational awareness, gained through NEC/NCW, there are no technical reasons why UCAS could not carry out the full range of combat air tasks currently undertaken by manned aircraft. The US is examining a variety of systems that may partially achieve this aim. The US Navy's UCLASS programme is an exemplar, with the Northrop Grumman X-47B UCAS-D as a potential system. However, this system has not been designed to gain control of the air in all domains.

This thesis has examined the advantages of extended range and endurance, and the potential for swifter and more efficient actions, that UCAS bring to warfare. The utility of UCAS warrants full investigation, including that of gaining control of the air, in its entirety. There is currently a lack of synergy and clear thought on their future effectiveness, particularly within the UK, which requires cogent and informed input. The findings of this thesis confirm that there are few reasons why UCAS should not be considered for the counter-air role, indeed, it is essential that this be done. The debate appears to have stalled; this thesis will help take the debate forward, allowing value to be added to the procurement process and helping to inform future policy decisions over the manned versus unmanned debate. If unable to control the air, at whatever range is necessary, all other military operations are drastically curtailed. Ultimately, unless there is some other programme capable of achieving control of the air in a peer on peer conflict, one in which A2/AD doctrine is dominant, the author believes that the development of UCAS able to conduct this task is essential. These systems would offer a potential revolution in the way warfare is conducted in the 21st Century.

Appendix A: Probability of a Kill Formula

P_k Formula[1202]

P_H = Probability of a Hit

P_F = Probability of Fuzing

P_K = Probability of a kill = $P_H P_{K/H}$

P_{ES} = Probability of escape

P_{SSK} = Probability of a single shot kill

n = The 'power' of the number of AAM fired

$1 - (P_{ssk})^n = P_{es}$

$1 - P_{es}^{(n)} = P_k \quad P_k = 1 - (1 - P_{ssk})^n$

Therefore, in the case of one AAM being fired with a P_{ssk} of .85:

$P_k = 1 - (1 - .85)^n = 1 - .15^1 = \underline{.85}$

If two AAM are fired with a P_{ssk} of .85

$P_k = 1 - (1 - .85)^2 = 1 - .15^2 = 1 - .022 = \underline{.978}$

The following examples illustrate how AAS P_k is increased with an increase in the salvo of AAM fired:

P_k of .15

If 2 AAM are fired, which have a **P_{ssk}** of .15 ($P_{es} = .85^2 = .723$) the P_k is (1 - .723 = **.278**)

If 4 AAM are fired, which have a **P_{ssk}** of .15 ($P_{es} = .85^4 = .522$) the P_k is (1 - .522 = **.478**)

If 8 AAM are fired, which have a **P_{ssk}** of .15 ($P_{es} = .85^8 = .272$) the P_k is (1 - .272 = **.728**)

P_k of .75

If 1 AAM is fired, which has a **P_{ssk}** of .75 ($P_{es} = .75 = .25$), the P_k is (1 - .25 = **.75**)

If 2 AAM are fired, which have a **P_{ssk}** of .75 ($P_{es} = .25^2 = 1 - .06$), the P_k is (1 - .06 = **.94**)

If 3 AAM are fired, which have a **P_{ssk}** of .75 ($P_{es} = .25^3 = 1 - .016$), the P_k is (1 - .016 = .**984**)

Kill Probability formula, with examples of the effects of multiple salvos of AAM

It is emphasised that calculating AAM P_k is not exact. Each AAM launched will meet slightly different conditions, because, unless all are launched at exactly the same time, and are subjected to exactly the same physical constraints and counter-measures, the formula is not exact. However, the formula gives the best indication of likely AAM effectiveness, and is considered satisfactory for the purpose of AAS development.[1203]

[1202] Ball, *op, cit.*, pp.2-5.

[1203] For an explanation of the effects that height, speed, warheads, and other factors have on an AAM, see Hewson, *op. cit.*, pp.23-24.

Appendix B: All Air-to-Air Kill Data: 1965 to Date

ALL AIR-TO-AIR KILL DATA				
CONFLICTS	**Total Air-to-Air Kills**	**Gun Kills**	**Infrared AAM Kills**	**RF AAM Kills**
1965-1991 Gulf War				
US: 1965-68 / Vietnam[1204]	**117**	**40 - (34%)**	**51 - (44%)**	**26 - (22%)**
Israel: 1967 / 6 Day War[1205]	**60**	**59 – (98.3%)**	**1 – (1.7%)**	**0**
US: 1971-73 / Vietnam[1206]	**73**	**7 - (9%)**	**34 - (47%)**	**32 - (44%)**
Israel: 1973 / Yom Kippur[1207]	**261**	**85 - (33%)**	**171 - (65%)**	**5 - (2%)**
UK: 1982 / Falkland's War	**21[1208]**	**2[1209]- (9.5%)**	**19[1210] - (90.5%)**	**0**
Israel: 1982 / Bekaa Valley	**82[1211]**	**8 - (9%)**	**62 - (76%)**	**12 - (15%)**
TOTAL – Pre - 1991	***614***	***201 – (32.7%)***	***338 – (55%)***	***75 – (12.3%)***
1991 Gulf War to Date				
US: 1991 / Desert Storm[1212]	**35**	**2 - (5.7%)**	**11 - (31.4%)[1213]**	**22 - (62.9%)**
US: 1992-94/ Iraq[1214]	**4[1215]**	**0**	**1 - (25%)**	**3 - (75%)**
US: 1994 / Bosnia[1216]	**4**	**0**	**3 - (75%)**	**1 - (25%)**
US / Holland: 1994 & 1999 / Bosnia & Kosovo[1217]	**6**	**0**	**0**	**6 - (100%)**
TOTAL – From 1991	***49***	***2 – (4.1%)***	***15 – (30.6%)***	***32 – (65.3%)***
TOTAL	***663***	***203 – (30.7%)***	***353 – (53.2%)***	***107 – (16.1%)***

1204 Burton, *op. cit.,* slide.3.

1205 Nordeen, *op. cit.,* pp.100-102

1206 *Project Red Baron III: Air-to-Air Encounter in Southeast Asia, Volume III: Analysis – Part 1: Tactics, Command & Control and Training*, p.55. In addition, one MiG-19 and one MiG-21 were induced losses, caused by running out of fuel, *ibid*.

1207 Burton, *op. cit..,* slide.3.

1208 Ethell and Price, *op. cit.,* pp.214-215.

1209 *ibid.*

1210 Stillion and Perdue, *op. cit.,* PPF.27.

1211 Grant, 'The Bekaa Valley War', p. 62.

1212 Watts and Kearny, *op. cit.,* Part II, p.113.

1213 Forty-eight AIM-9Ls were launched – see Stillion and Perdue, *op. cit.,* PPF.28.

1214 Air Force Historical Research Agency, *op. cit.*

1215 Two kills were 'blue on blue' (fratricide), when two USAF F-15Cs shot down two UH-60 Blackhawk helicopters.

1216 Air Force Historical Research Agency, *op. cit.*

1217 Stillion and Perdue, *op. cit.,* p.25. See also, Air Force Historical Research Agency, *op. cit.*

Appendix C: Radar Air-to-Air Missile Data: 1965 to Date

RADAR AIR-TO-AIR MISSILES						
CONFLICTS	**Total Shots**	**Total Kills**	**P_K**	**BVR Shots**	**BVR Kills**	**BVR P_K**
1965 – 1991 Gulf War						
US: 1965-73 Vietnam[1218]	**918**	**58**	**.06**	**92**	**2**	**.02**
Israel: 1967 / 6 Days War	**0**	**-**	**-**	**-**	**-**	**-**
Israel: 1973 Yom Kippur[1219]	**12**	**5**	**.42**	**1**	**1**	**1.0**
UK: 1982 Falkland's War[1220]	**0**	**-**	**-**	**-**	**-**	**-**
Israel: 1982 Bekaa Valley[1221]	**23**	**12**	**.52**	**2**	**1**	**.50**
TOTAL – Pre - 1991	***953***	***75***	***.08***	***95***	***4***	***.04***
1991 Gulf War to Date						
US: 1991 / Gulf War[1222]	**67**	**22**	**.33**	**29**	**16**	**.55**
US: 1992-94 Iraq NFZ[1223]	**3**	**3**	**1.0**	**2**	**2**	**1.0**
US: 1994 Bosnia NFZ[1224]	**1**	**1**	**1.0**	**0**	**0**	**0**
US / Holland: 1994 & 1999 Bosnia & Kosovo NFZ[1225]	**13**	**6**	**.46**	**9**	**4**	**.44**
TOTAL – From 1991	***84***	***32***	***.38***	***40***	***22***	***.55***
TOTAL: 1965 to Date	***1037***	***107***	***.10***	***135***	***26***	***.19***

[1218] Burton, *op. cit.,* slides 3 and 5.

[1219] *ibid.,* slides 3, 4 and 5.

[1220] Although Argentina's Air Force possessed and did launch Matra-350 RF AAM at British Sea Harriers, no kills were achieved. The Sea Harrier did not possess RF AAM - see Ethell and Price, *op. cit.,* p.61.

[1221] Burton, *op. cit.,* slides 3, 4 and 5.

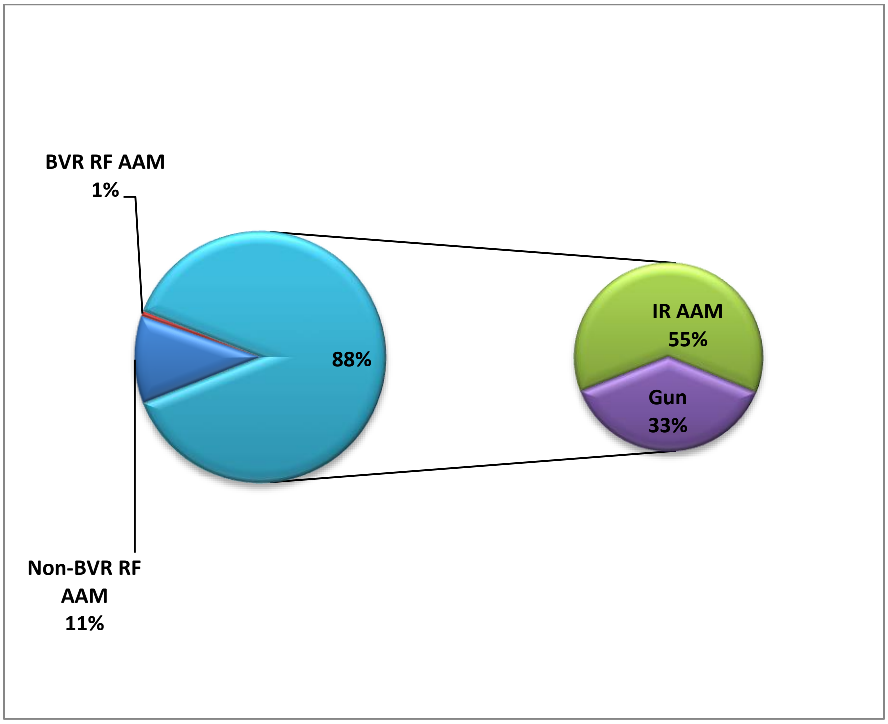
[1222] Watts and Keany, *op. cit*., Also see Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*, p.43.

[1223] One kill was fratricide, with an AIM-120 employed by a US F-15C on a friendly UH-60 Blackhawk helicopter.

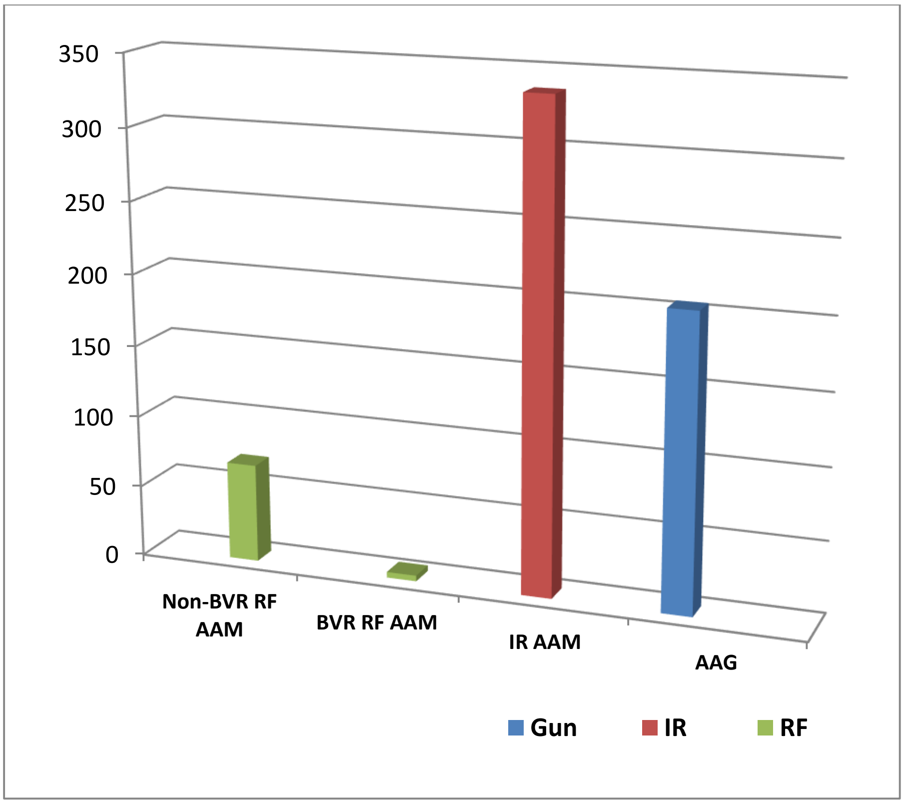
[1224] Air Force Historical Research Agency, *op. cit.*

[1225] Stillion and Perdue, *op. cit.,* PPF.25. See also, Air Force Historical Research Agency, *op. cit.*

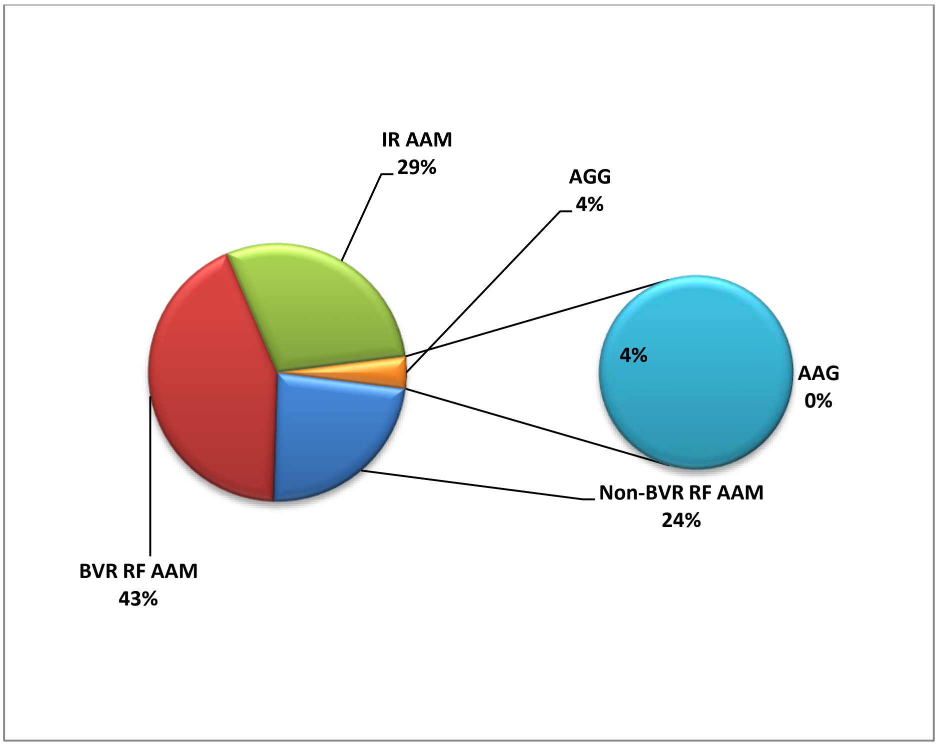
Appendix D: 1965 to Date Air-to-Air Kills



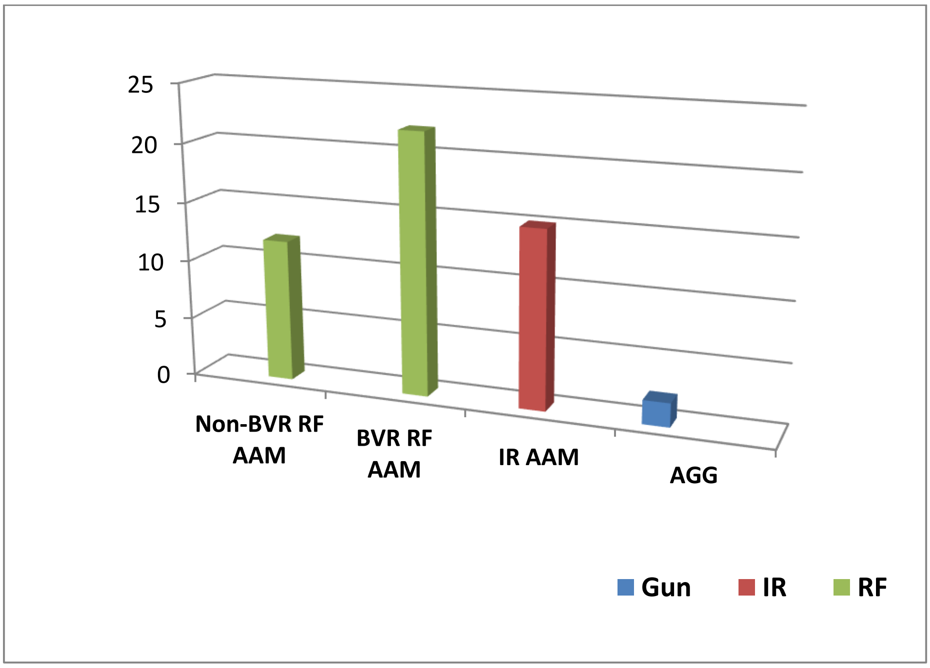
1965 to Pre-1991 Gulf War air-to-air kills



1965 to Pre-1991 Gulf air-to-air kills



1991 Gulf War to date air-to-air Kills



1991 Gulf War to date air-to-air kill

While not classic air-to-air engagements, two A-10 Thunderbolt ant-tank aircraft used their air-to-ground gun to destroy two Iraqi helicopters during the 1991 Gulf War.

Appendix E: RED fighters v BLUE fighters Air-to-Air System Kill Probability

Fighters	BVR Air-to-Air System P_k					
	1.0	**0.9**	**0.75**	**0.50**	**0.25**	**0.10**
BLUE AMRAAM Fired (Total 144)	***72***	***144***	***144***	***144***	***144***	***144***
RED PL-12 Fired (Total 720)	***24***	***48***	***51***	***102***	***234***	***586***
BLUE Fighters killed	**24**	**24**	**24**	**24**	**24**	**24**
RED Fighters Killed	**72**	**72**	**68**	**34**	**15**	**6**
BLUE Fighters Survive	**0**	**0**	**0**	**0**	**0**	**0**
RED Fighters Survive	**0**	**0**	**4**	**38**	**57**	**66**

24 BLUE fighters verus 72 RED fighters remaining against kill probabilities

Fighters	BVR Air-to-Air System P_k					
	1.0	**0.9**	**0.75**	**0.50**	**0.25**	**0.10**
BLUE AMRAAM Fired (288)	72	144	154	286	288	288
RED PL-12 Fired (720)	48	97	102	205	467	708
BLUE Fighters killed	**48**	**48**	**48**	**48**	**48**	**29**
RED Fighters Killed	**72**	**72**	**72**	**67**	**29**	**11**
BLUE Fighters Survive	**0**	**0**	**0**	**0**	**0**	**19**
RED Fighters Survive	**0**	**0**	**0**	**5**	**43**	**61**

48 BLUE fighters verus 72 RED fighters remaining against kill probabilities

These tables illustrates the factor that AAS P_k has on counter-air effectiveness, and the properties of aircraft and AAM mass in numbers.

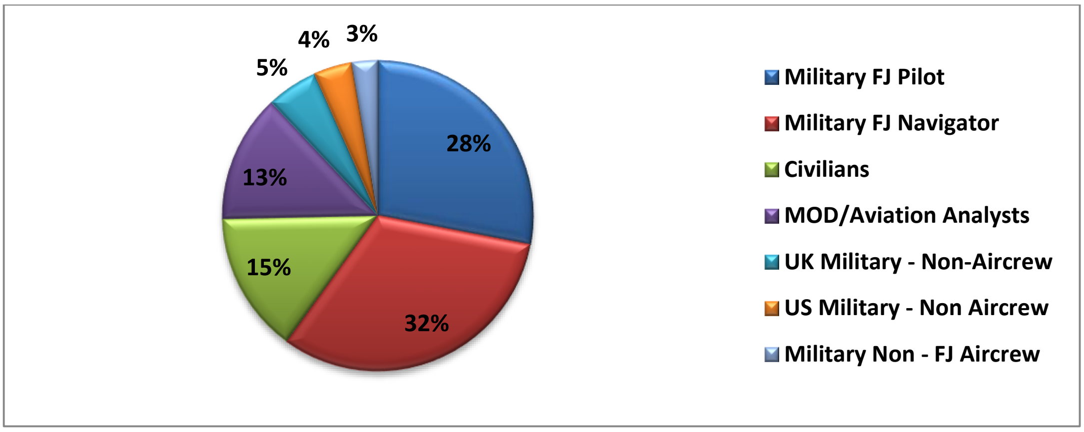
Appendix F: NASA's Function-specific Level of Autonomy and Automation Tool (FLOAAT)

Level	Observe	Orient	Decide	Act
5	Data monitored on-board without assistance from ground support.	Calculations performed on-board without assistance from ground support.	Decision made on-board without assistance from ground support.	Task executed on-board without assistance from ground support.
4	Majority of monitoring performed on-board, will available assistance from ground support.	Majority of Calculations performed on-board, will available assistance from ground support.	Decision performed on-board, will available assistance from ground support.	Task performed on-board, will available assistance from ground support.
3	Data is monitored both on-board and on the ground.	Calculations are performed both on-board and on the ground.	Decisions are made both on-board and on the ground, and the final decision is negotiated between them.	The task is executed with both on-board and ground support.
2	Majority of monitoring performed by ground support, will available assistance on-board.	Majority of calculations performed by ground support, will available assistance on-board.	Decision made by ground support, with available assistance on-board.	Task executed by ground support, with available assistance on-board.
1	Data monitored on ground, without assistance from on-board.	Calculations performed on ground, without assistance from on-board.	Decision made on ground, without assistance from on-board.	Task executed by ground support, without assistance from on-board.

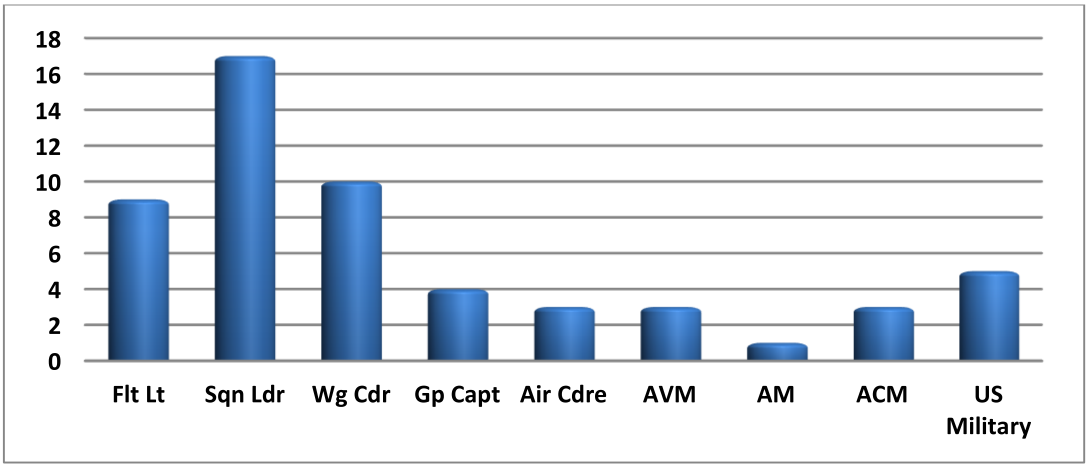
The author's five levels of autonomy are based on NASA's FLOAT.[1226]

[1226] Proud and Hart, *op. cit.*, p. 6.

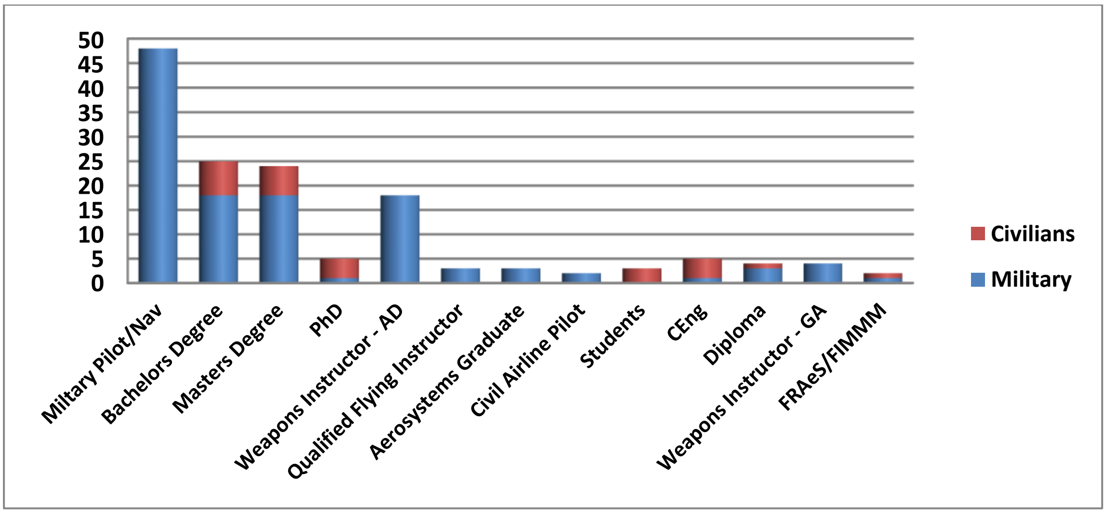
Appendix G: Interviewee Domestics



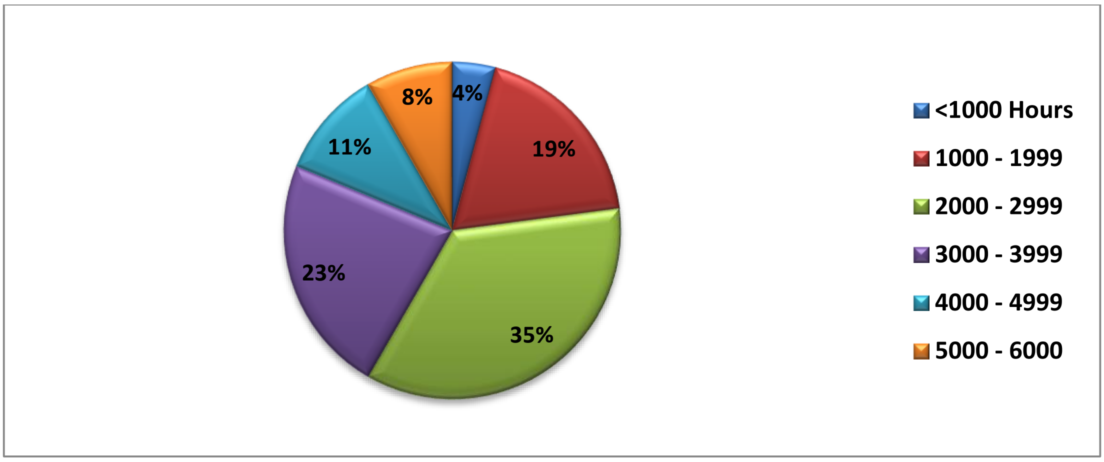
Interviewee professions



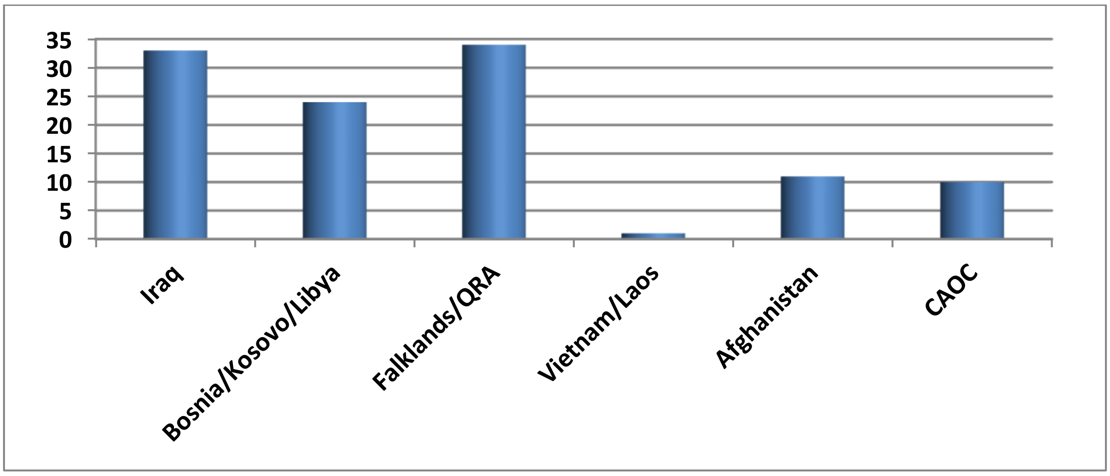
Interviewee military rank



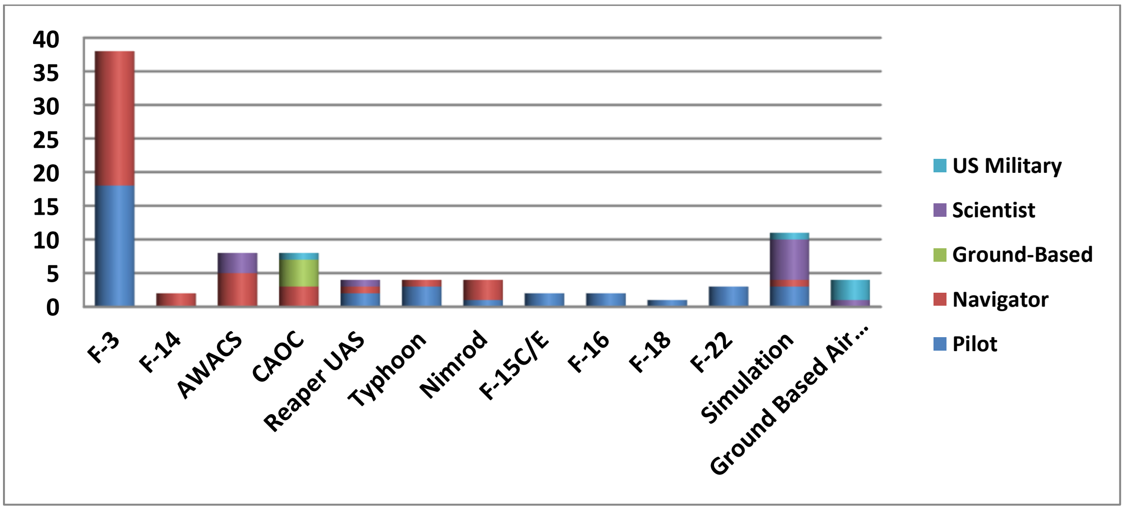
Interviewee professional and academic qualifications



Interviewee military flying experience



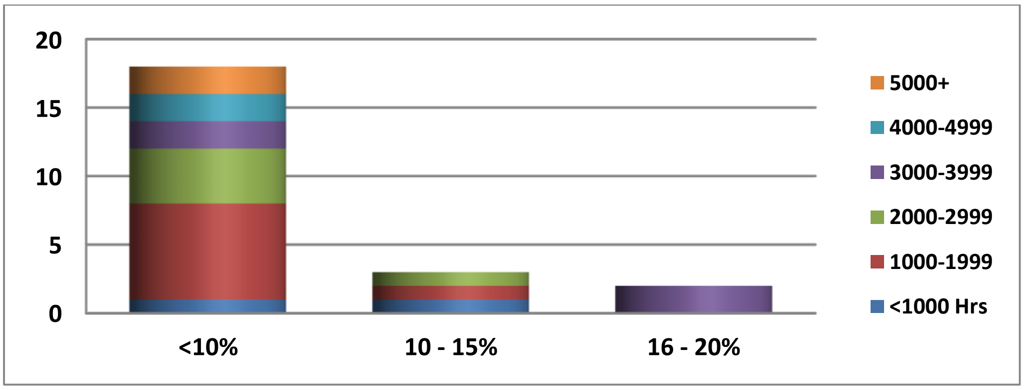
Interviewee operational experience



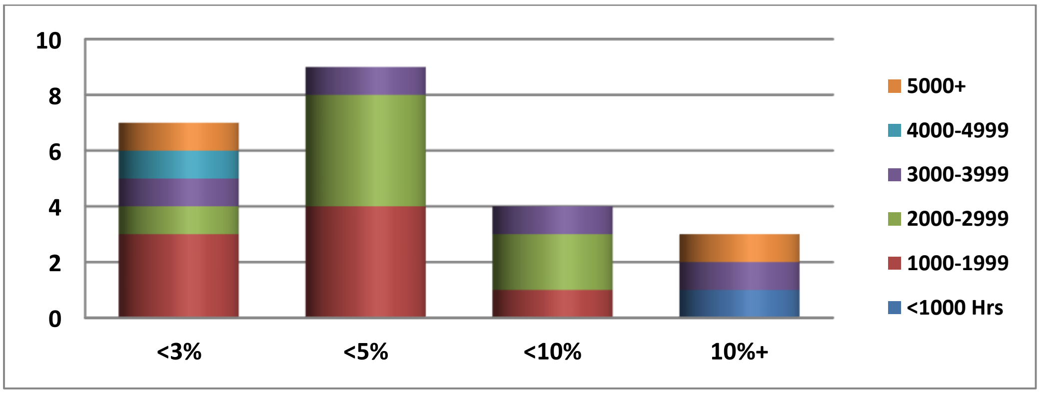
Interviewee Tactical Data-Link/NEC experience

Appendix H: Interviewee Responses

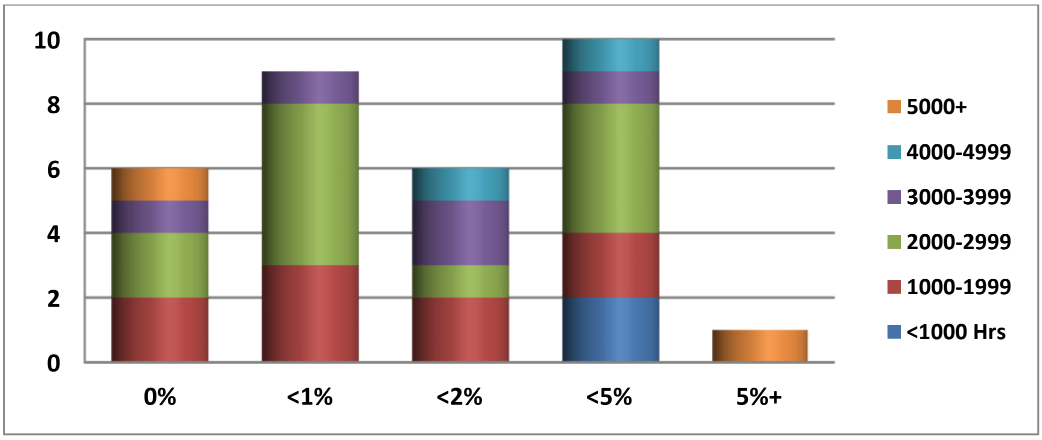
<u>**Requirement to Conduct Visual Manoeuvring to Achieve a Kill**</u>



BVR Engagements - Requirement to enter the visual merge to kill an adversary, as a percentage of sorties, during LFE/COMAO training exercises

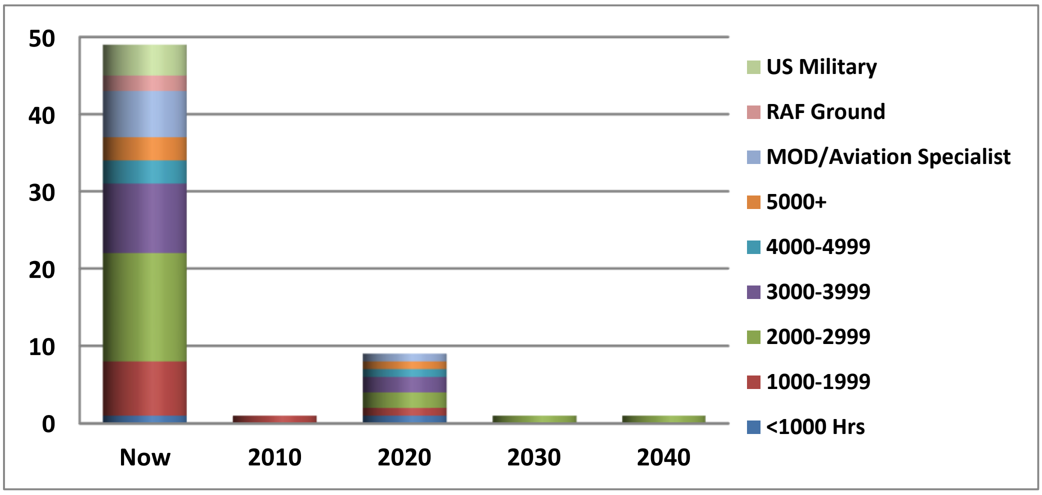


WVR Engagements - Requirement to conduct air combat manoeuvring to achieve a kill, as a percentage of sorties, during LFE/COMAO training exercises

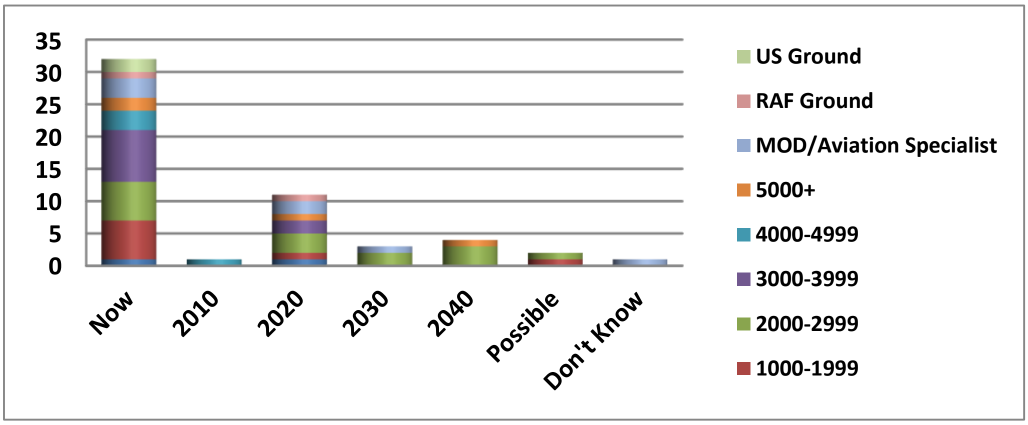


Requirement to use the AAG in visual air combat, as a percentage of sorties, during LFE/COMAO training exercises

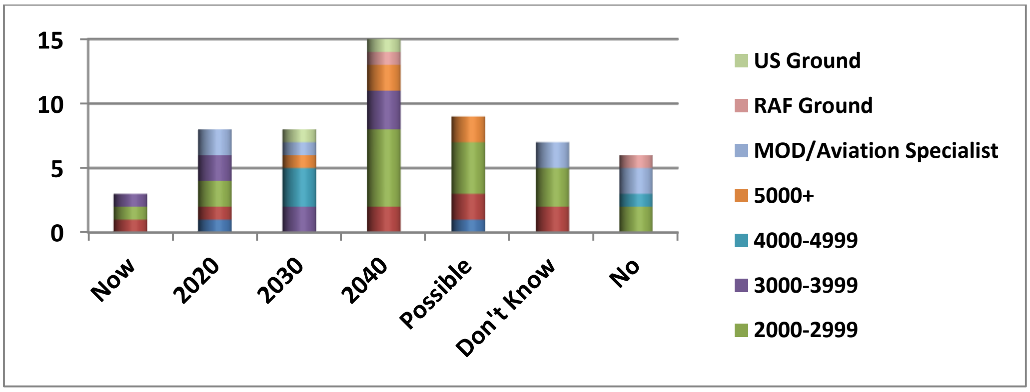
Third-Party Targeting



BVR Third-Party Targeting

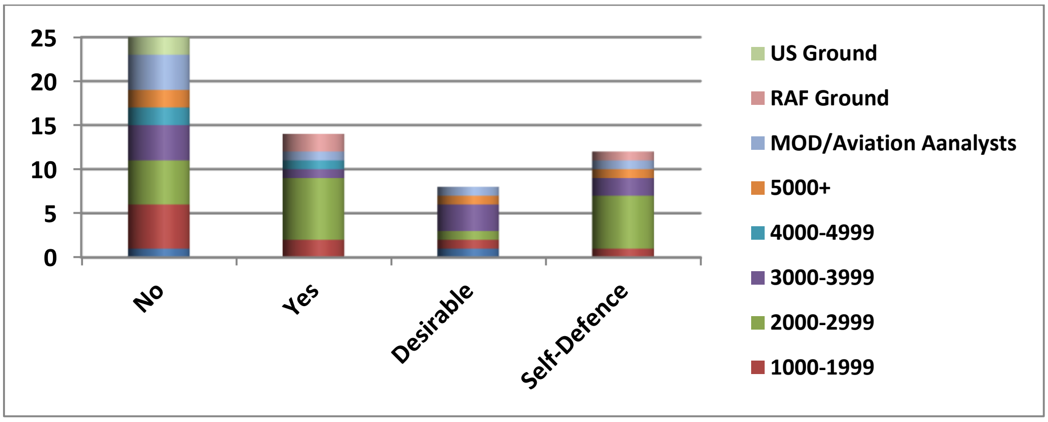


WVR Third-Party Targeting

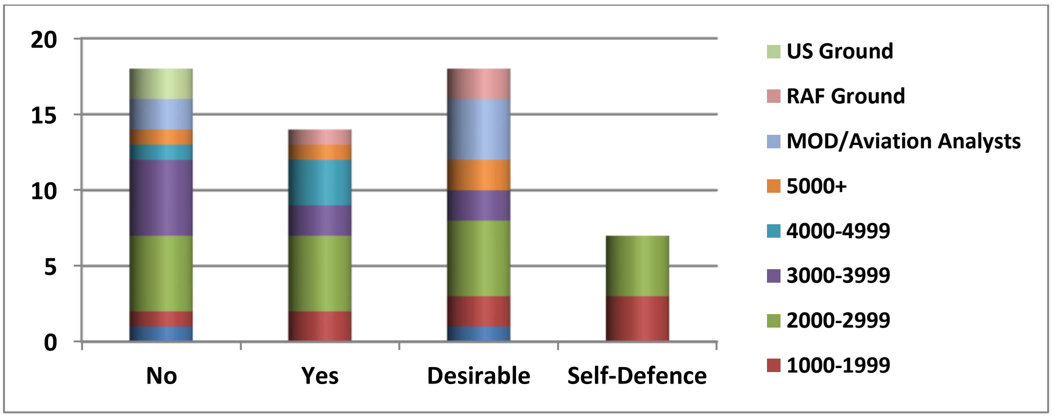


Close Combat Third-Party Targeting

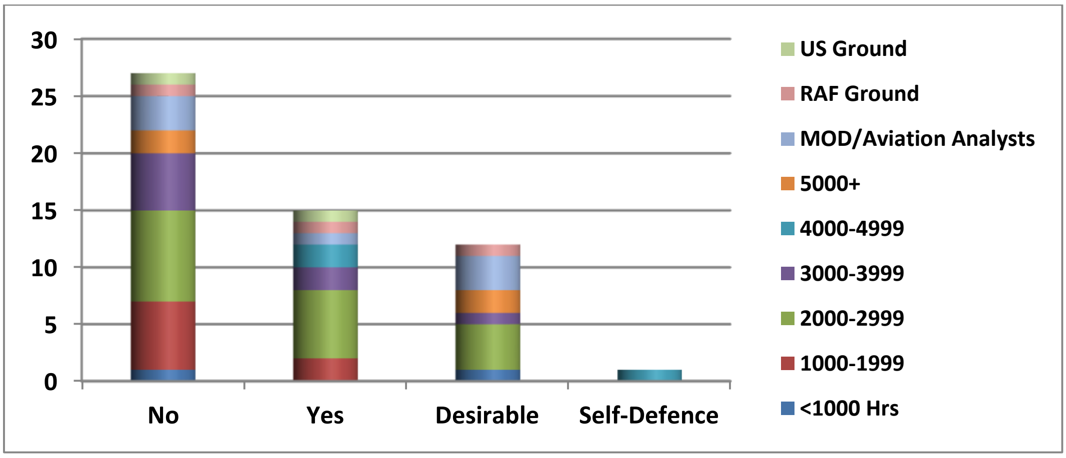
UCAV and Manned Fighter Agility



Requirement for UCAV to be highly agile in 2040

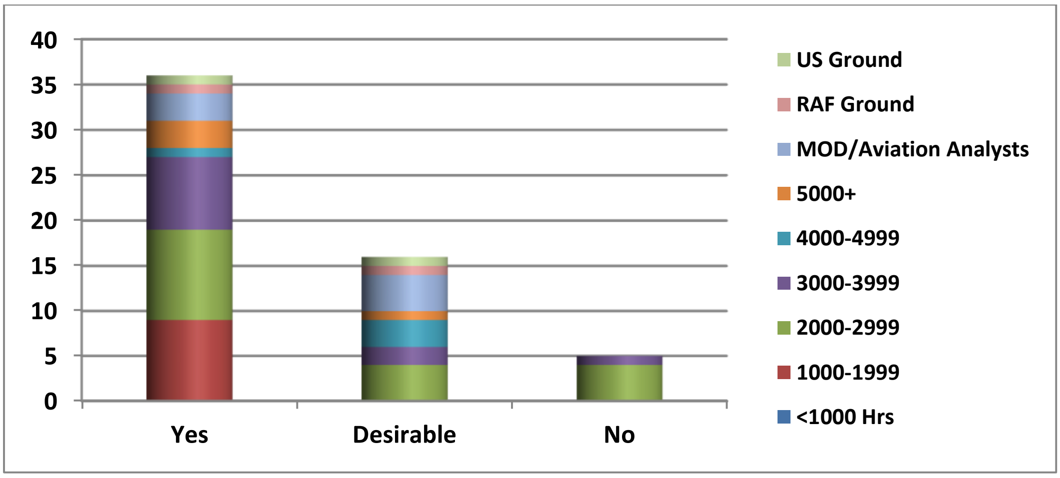


Requirement for manned fighter to be highly agile in 2040

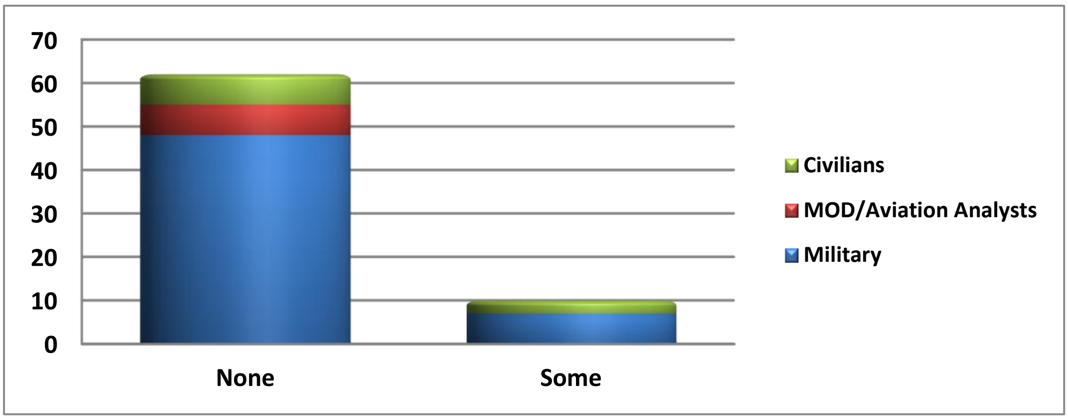


Requirement for UCAV to conduct highly agile visual air combat

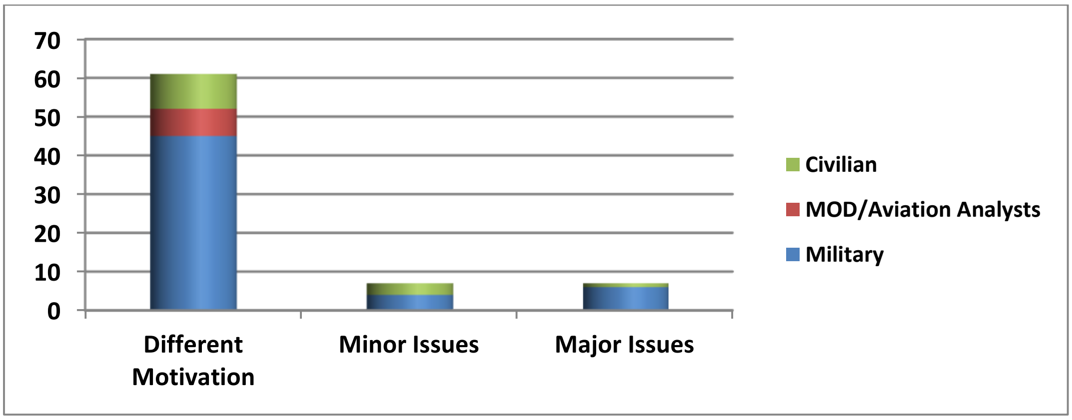
Stealth, Moral and Political Implications



Will stealth be crucial?

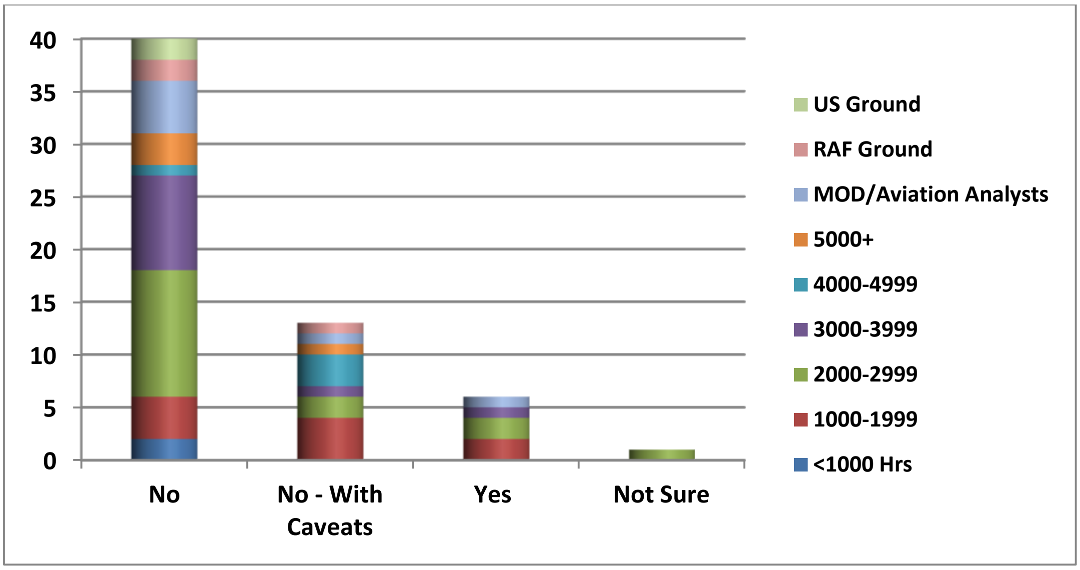


Moral and political concerns

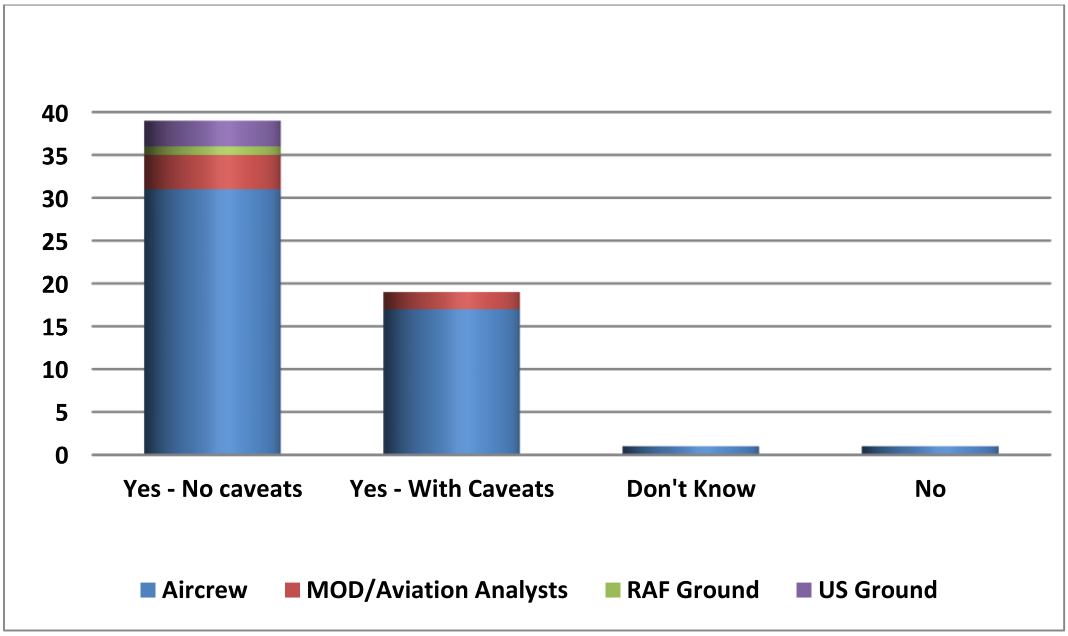


Motivation to join an air force

Is a manned fighter necessary in order to gain control of the air?



Requirement to have a pilot in fighter aircraft in 2040



Could UCAS effectively conduct counter-air missions in 2040?

Appendix I: International UCAS Developments

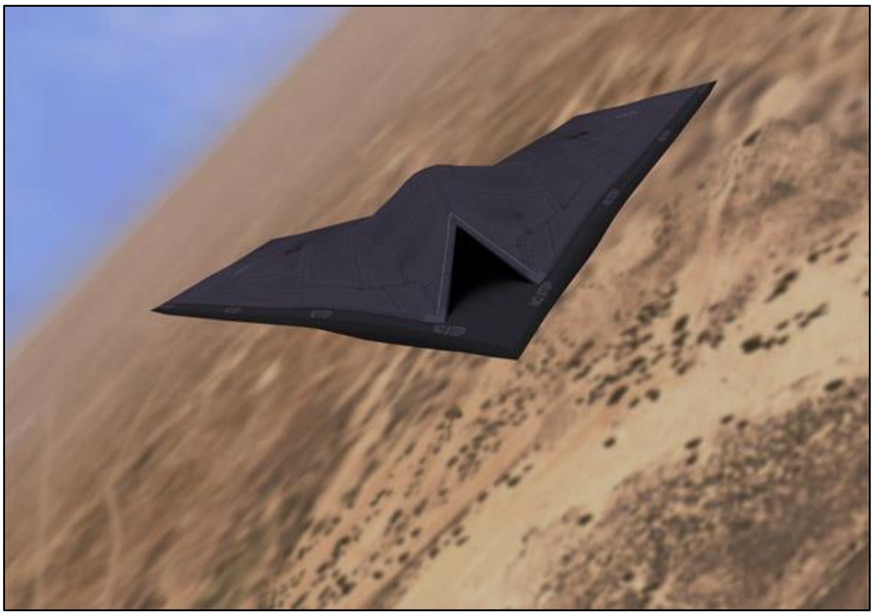
Northrop Grumman's X-47 UCAS. [1227]

Artist's impression of *Dark Sword (An Jian)*, from a model shown at the 2006 Zukhai Air Show.[1228]

[1227] Northrop Grumman, 'X-47B in Flight', http://www.as.northropgrumman.com/products/nucasx47b/assets/lgm_UCAS_3_0911.jpg, (accessed 11 December 2011).

[1228] Kospoth, *op. cit.*

Russia's *Skat* UCAS.[1229]



Artist's impression of BAE's *Taranis* UCAS.[1230]

[1229] Brandon Hill, 'Mig Unveils Skat Unmanned Combat Air Vehicle', *DAILYTECH*, http://www.dailytech.com/MiG+Unveils+Skat+Unmanned+Combat+Air+Vehicle/article8589.htm, (accessed 5 May 2009).

[1230] ''Taranis, United Kingdom', *airforce-technology.com.,* http://www.airforce-technology.com/projects/tanaris/, (accessed 9 September 2010).

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Responders to Questionnaire

The interviews and questionnaire responses were conducted under King's College London's Research Ethics mandate. The interviewees were made aware of the use to which the interview derived material would be put, and were given the option of providing anonymous feedback, under the 'Chatham House Rule'.

Military

Air Chief Marshal Sir Simon Bryant RAF: Commander-in-Chief Air Command; Tornado F-3/F-4 Phantom/F-14 Tomcat, Navigator– interviewed 30 March 2010

Air Chief Marshal Sir Stephen Dalton RAF: Chief of the Air Staff; Jaguar/Tornado GR-1, Pilot – interviewed 12 January 2010

Air Chief Marshal Sir Glen Torpy RAF: Tornado GR1, Pilot; Ex-Chief of the Air Staff, 2006 - 2009 – interviewed 11 October 2011

Air Marshal Christopher Nikols RAF: Tornado GR1/Jaguar, Pilot; Chief of Defence Intelligence – interviewed 12 September 2011

Air Vice-Marshal Paul Colley RAF: Tornado F-3/F-4 Phantom, Navigator; Qualified Weapons Instructor, Assistant Chief of Defence Staff (Concepts and Doctrine) – interviewed 4 March 2010

Air Vice-Marshall Ross Paterson RAF: Chief Executive, Services' Pay and Veterans' Agency – interviewed 9 April 2010

Major General Lawrence Wells USAF: F-16, Pilot; Commander, US 9th Air Force, Air Combat Command – email response, 2 December 2012.

Air Commodore Richard Atkinson RAF: Tornado F-3/F-4 Phantom, Pilot; Qualified Weapons Instructor, Air Officer Scotland and Station Commander RAF Leuchars – interviewed 10 August 2009

Air Commodore Gordon Moulds RAF: Tornado F-3/F-4 Phantom, Navigator; Commander British Forces Falkland Islands – interviewed 1 July 2009

Air Commodore Richard Powell RAF: Tornado F-3/F-4 Phantom/F-14 Tomcat, Navigator; Qualified Weapons Instructor, Station Commander RAF Waddington – interviewed 11 November 2009

Group Captain Simon Hindemarsh RAF: Tornado F-3/F-4 Phantom, Navigator; Qualified Weapons Instructor, Chief of Staff, Falkland Islands – interviewed 29 May 2009

Group Captain Tony Innes RAF: Tornado F-3/F-4 Phantom/Typhoon, Pilot; Qualified Weapons Instructor, Station Commander RAF Leeming – mail response 1 April 2010

Group Captain Paul Taylor RAF: Tornado F-3/F-4 Phantom/E3-D, Navigator; MOD Operations Directorate – interviewed 5 November 2009

Group Captain Alan Vincent RAF (Retd): Buccaneer/Tornado GR1, Navigator; Group Leader DSTL – email response 2 April 2010

Colonel Gaillard Peck USAF (Retd): Phantom/F-15 + Aggressor, Pilot; USAF Weapons School Instructor – email response 11 April 2010

Wing Commander Jeremy Attridge RAF: Tornado F-3/F-18C/Typhoon, Pilot; Qualified Weapons Instructor, MOD Capability Theatre Airspace – Interviewed 20 December 2011

Wing Commander Andrew Dickens RAF: Tornado F-3, Pilot; RAF Air Warfare Centre, Head of Trials and Tactics – interviewed 15 May 2009

Wing Commander Hugh Griffiths RAF (Retd): Tornado F-3, Navigator; Qualified Weapons Instructor; Director – Inzpire Ltd – mailed response 28 March 2010

Wing Commander Mike Humphreys RAF (Retd): Tornado GR1/4, Navigator; UAS Business Development Director BAE – mail response 6 April 2010

Wing Commander Richard Knight RAF: Tornado F-3, Navigator – interviewed 1 May 2009

Wing Commander Mike Lumb RAF: Tornado GR1/4, Navigator; DSTL Military Adviser – interviewed 1 April 2010

Wing Commander Justin Reuter RAF: Tornado F-3, Navigator; Qualified Weapons Instructor; Assistant Head MOD Capability EPA – interviewed 2 November 2010

Wing Commander Chris Thirtle RAF: Tornado F-3/F-15E, Pilot; MOD Chief of the Air Staff's UAS Strategy – interviewed 12 January 2010

Wing Commander Mark Wakeman RAF (Retd): Tornado F-3/F-4 Phantom, Navigator; Qualified Weapons Instructor – interviewed 9 January 2010

Wing Commander Paul Wallace RAF: Buccaneer/Tornado GR-1/4, Navigator; UCAS Analyst – email response 25 February 2010

Squadron Leader Dr Richard Birchenall RAF: Communications Engineer and IADS Specialist – interviewed 14 October 2010

Squadron Leader Ian Brain RAF: Tornado F-3/F-4 Phantom/Wessex, Navigator – email response 19 February 2010

Squadron Leader Edward Burrows RAF: Tornado F-3, Pilot; Qualified Flying Instructor – interviewed 13 January 2010

Major Charles Ware USAF: Aeronautical Engineer – interviewed 5 June 2013

Squadron Leader Steven Davis RAF: Nimrod R1/2, Air Electronics Operator; IADS Specialist – interviewed 24 August 2010

Squadron Leader Jonny Farrow RAF: Tornado F-3, Navigator; Qualified Weapons Instructor – email response 24 February 2010

Squadron Leader Sue Freeman RAF: Tornado F-3, Pilot; Qualified Flying Instructor – interviewed 13 June 2009

Squadron Leader Adam Grindley RAF: Buccaneer/Tornado GR1/4, Navigator; DSTL Military Adviser – mail response 6 April 2010

Squadron Leader Fredrick Grundy RAF (Retd): Tornado F-3/F-4 Phantom, Pilot; Qualified Weapons Instructor – interviewed 25 October 2009

Squadron Leader Martin Higgins RAF: Tornado F-3, Pilot; Qualified Flying Instructor – 17 June 2009

Squadron Leader Steven Kilvington RAF: Tornado F-3, Navigator; Qualified Weapons Instructor – interviewed 3 February 2010

Squadron Leader Andrew Miller RAF: Tornado F-3, Navigator; Qualified Weapons Instructor – interviewed 25 April 2009

Squadron Leader Matthew Nicolas RAF: Tornado F-3, Navigator, Qualified Weapons Instructor – interviewed 22 October 2009

Squadron Leader Kenneth Reeves RAF: Tornado F-3/F-4 Phantom, Navigator; Qualified Weapons Instructor – interviewed 11 August 2009

Squadron Leader David Richards RAF: Tornado F-3/GR-4, Navigator – interviewed 3 December 2009

Squadron Leader David Smith RAF: Battlespace Manager – interviewed 20 January 2010

Flight Lieutenant Mike Hearnshaw RAF: Tornado F-3, Pilot – interviewed 27 April 2009

Flight Lieutenant James Hunkin RAF: Tornado F-3, Pilot – interviewed 25 April 2009

Flight Lieutenant Russell Jones RAF (Retd): Tornado F-3/F-4 Phantom, Pilot – interviewed 10 April 2010

Flight Lieutenant Roy MacIntyre RAF: Tornado F-3/F-4 Phantom, Pilot – Qualified Weapons Instructor – email 19 April 2009

Flight Lieutenant Gerard McCormick RAF: Tornado F-3, Navigator – interviewed 28 April 2009

Flight Lieutenant Andrew Shaw RAF: Tornado F-3/F-18 Pilot – interviewed 29 April 2009

Flight Lieutenant Jonathan Skinner RAF: Tornado F-3/Typhoon, Pilot – mail response 24 March 2010

Flight Lieutenant Jonathan Smith RAF: Tornado F-3/F-22 Raptor, Pilot; Qualified Weapons Instructor – interviewed 3 February 2010

Flight Lieutenant Jennifer Trafford: Tornado F-3, Navigator – mailed response 22 March 2010

Captain Michael Mashoe USMC, Ground Air Defence Commander – interviewed 2 April 2010

<u>Aviation Analysts</u>

David Bromley: MOD UAS Aviation Analyst – interviewed 15 June 2011

Alan Brooke: Home Office Scientist; UAS Specialist – interviewed 3 May 2010

Professor Tony Gillespie: UCL Professor/DSTL Scientist – Autonomy and Artificial Intelligence – email response 1 April 2010

John Keirl: DSTL Scientist; UAS/UCAS Lead – interviewed 27 November 2009

Harjit Lota: DSTL Scientist; UAS and Weapons Specialist – interviewed 3 May 2010

Dr Simon Lovell: DSTL Scientist, Future Air Systems – interviewed 4 March 2010

Keith Payne; Aviation Engineer – interviewed 16 December 2011

Dr Jon Platts: Artificial Intelligence and Autonomy Specialist – mailed response 20 December 2010

Civilians

Alan Bell: Engineer – interviewed 3 April 2010

Callum Murray: Retired Royal Marine Officer/Businessman – interviewed 8 March 2010

Polly Murray: Bespoke Furniture Designer – interviewed 8 March 2010

Stephen Oxnard: University Student – interviewed 8 April 2010

Angus Paterson: Student – interviewed 9 April 2010

Myles Paterson: University Student – interviewed 9 April 2010

Lynne Todd: Certified Engineer and Materials Scientist – interviewed 3 April 2010

Marie Young: Retired Financial Consultant – interviewed 6 March 2010

Raymond Young: Retired Engineer – interviewed 6 March 2010

Oliver Waghorn: Special Adviser to the Secretary of State of Defence – interviewed 24 June 2011

Joanne Wills: Business Development Consultant – interviewed 31 January 2010

Chatham House Rule

Five interviewees chose to respond under the Chatham House Rule, including an RAF pilot, an ex-Senior Responsible Officer for the MOD's Information and Superiority capabilities, an aviation consultant and a USAF army officer specialising in counter-air systems.

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